THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. XIII., No. 3. 1887. Whole No. 42.

[COPYRIGHTED.]

PRIZE ESSAY FOR 1887.

"In hoc signo vinces."

THE NAVAL BRIGADE: ITS ORGANIZATION, EQUIPMENT, AND TACTICS.

BY LIEUTENANT C. T. HUTCHINS, U. S. Navy.

CONTENTS.

I.—ORGANIZATION.

The necessity for landing of sailors and marines.—The Naval Brigade in the labor riots of 1877; at Alexandria, Egypt, in 1883; on the Isthmus of Panama in 1885.—Opposition in the service to the Naval Brigade and the landing of sailors.—The French sailors and marines in the Franco-Prussian war and at Sfax.—The English sailors and marines in the Ashantee war, and in Egypt and the Soudan.—Formation of the Brigade; number of men to an infantry company.—Necessity of landing men under the command of their own officers.—The commander of the Naval Brigade.—The ship's battalion, men and officers.—The number of men in an artillery company.—Landing of artillery.—Battalion of U. S. S. Atlanta and her class.—Machine guns.—Limbers.—Forming the Brigade: officers, men, guns, etc.—Marines.—Intelligence staff: duties, officers, men, and outfit.—Sanitary precautions.—Duties of chief medical officer.—Transport vessels.—Preparation of orders by the commander of Brigade. . . 304-315

II.—EQUIPMENT.

Transportation of ammunition.—Supplying ammunition to the fighting line.—Arms carried by artillerymen.—"Light marching order."—"Heavy marching order."—Arms carried by officers and men.—Men's equipments.—Ammunition passers and carriers, and their equipment.—Medical force.—Dress of officers and men.—Gun-cotton for blowing up buildings.—Armed railroad cars.—Weight of articles carried by the men.—Strength of a naval brigade of twenty companies and ten pieces of artillery.—Marines: arms, ammunition, and articles carried on the march.—Rations: quality, manner of packing and stowing. 315-324

III.—TACTICS.

Changes required by modern conditions of war.—Tel-el-Kebir.—Changes in the manual of arms.—Upton's Tactics.—Deploying the modern fighting line.—Instructions in loading and firing on shipboard.—Care of breech-loading firearms and ammunition.—Small-arm target practice and fire discipline.—Elementary light artillery tactics.—Grand tactics.—Disembarkation and landing of the Naval Brigade.—Equipment and outfit for boats.—"Order before landing."—Beach-master at landing-place of Brigade.—Marines: their tactics and drill.—Marches.—Advance guard.—Outposts.—Flank patrol.—Street fighting.—Pittsburg labor riots of 1877.—Bivouac.—Camping.—Camp routine.—Base.—Conclusions. 324-340

I.—ORGANIZATION.

To be successful in the landing of seamen and marines and in the operations on shore of the naval brigade, much will depend upon the previous system of organization and training of the personnel that will compose the force. The fact must not be lost sight of, that upon the amount of work in the care and preparation of the seaman to meet the requirements of detached service will his efficiency be measured.

To fulfill the demands of a hastily assembled fleet, with battalion organizations sometimes very dissimilar, and to unite the different ships' battalions into a homogeneous military force for landing, must, under the most favorable circumstances, prove a difficult task.

There has been, and probably always will be, some objection by naval men to the naval brigade and the landing of sailors for operations on shore. The legitimate sphere of the seaman being afloat, the landing of a naval force cannot be otherwise than incidental to the service. Any attempt to organize a ship's company with the infantry battalion as a basis would probably result in confusion and

disaster; to return to the days of the Invincible Armada and fill our ships with soldiers would be folly.

Under our system of government and the growing opposition to a large standing army, it must be apparent to the most conservative that the naval brigade is a pressing necessity.

The demand for landing parties from our ships and fleets, both at home and abroad, was shown during the labor riots in this country in 1877, at Alexandria, Egypt, in 1882, and more recently on the Isthmus of Panama in 1885. The organization and transportation to the Isthmus of Panama of a naval force in April of that year demands more than a passing notice. As a measure of quick despatch, economy, and the efficient work performed, the accomplishment of the desired results on this occasion was more than satisfactory, and a progressive and enterprising people like ours will never fail to lend support to a force which with the least expenditure of time and money accomplishes the desired work.

We still find some opposition on shipboard to-day among sailors to being landed as infantry; the growing and constant desire to turn the sailor completely into a soldier at these times, and his invariable opposition to this transformation, is the cause of want of success and lack of interest. But this opposition of the sailor may be easily overcome by judicious treatment, emulation, and a system of competition, not only between companies in ships' battalions, but between different ships; and with this interest once awakened, the regular landing day would be hailed with delight. No valid reason is apparent why the naval brigade should interfere with great guns or the marlinspike, if we stop what is known in the Navy to-day as show drills, theatrical in their effect and forced on the Navy by long custom. The absolute niceties of the soldier should be abolished in the drills of the ship's battalion. The time devoted to these unbusiness-like evolutions should be employed to some useful purpose, and the sailor not subjected to the strait-jacket drill every infantry day. Every ship's battalion should be landed frequently when in port, authorities and weather permitting. Once a week would not be too frequent for a cruising ship, and the brigade should be landed for several days in succession when the Admiral assembles his fleet for drill and inspection.

To land the naval brigade in opposition to well-organized and trained forces of infantry would not be expedient, but that a naval force would prove more than a match for any but regular soldiers

none can doubt. For street fighting, the trained seaman may be considered quite equal to the regular soldier. The economy of time in the transportation of a naval brigade along the seaboard or on our large rivers, thus avoiding any opposition a force would meet with in having to pass through cities to destination by rail, and its being ever ready, must make such a force always a desirable one. What sailors can accomplish when landed to co-operate with an army was well illustrated during the Franco-Prussian war, by the French seamen at the siege of Paris as artillerymen, and at Le Bourget as infantrymen. England, with her small standing army, has of late years placed great reliance upon her naval brigade. The conduct of her sailors and marines in the Ashantee war of 1873, and in Egypt and the Soudan in 1884, merits the greatest praise. One of the most brilliant exploits of a naval force was the landing of the naval brigade of the French fleet and taking of Sfax in July, 1881, when the electric light and the 1-pound Hotchkiss shell gun, mounted in ships' boats, were brought into use.

The Watch, Quarter, and Station Bills now supplied to all our naval vessels, call for a battalion with an officer to command called "Colonel Commanding," also other necessary officers. The battalion is composed of, first, the artillery, with an officer to command, each piece being in charge of a junior officer with a quarter gunner. Then follows the marine guard, forming the first company; next, the seamen forming the other companies, and last, the pioneers. This arrangement appears to work fairly well in the service, though in some vessels there are ammunition passers and carriers, and stretchermen to care for the wounded.

The term naval brigade is now applied to the battalions of two or more ships brigaded together for the purpose of landing for operations on shore. In uniting the different battalions under one head, each ship's battalion should land and fall in together; no separation of the companies of a battalion should be allowed if it can be avoided. In forming the brigade for exercise and drill, the music should form on the right of the line; then should follow the artillery battalion; next in order the first battalion of infantry, made up of the first company of marines, "Co. A," the second company of marines, "Co. B," etc.; then the second battalion of infantry, made up of the first company of sailors, "No. 1" company, the second company of sailors, "No. 2" company; next, the third battalion of infantry, and so on; and, last, pioneers and stretchermen—bearing in mind that all the

artillery of the force are to be kept together, as well as the companies of marines and the companies of sailors. Any division or breaking up of the full companies of marines, or of the companies composed of seamen of a ship's battalion, should not be thought of; men that are known to each other should be allowed to go into battle together and under their own company officers.

The great feeling of pride in one's own ship should be cultivated to the fullest extent, hence the necessity of keeping ships' battalions as intact as possible. In naming the companies, it will be seen that the marines have their companies distinguished by letters and the sailors their companies by numbers, which numbers in a ship's battalion are the same as those of their respective divisions, No. 1 company coming from the first division, and so on. Again, a numbered company would indicate that the company was composed of seamen.

A company of infantry should be composed of 40 men, with 2 guides, 2 file-closers, and 2 ammunition passers and carriers — in all 46 men. Companies should not be too large and unwieldy; large companies could only be a question of economy of officers, and in this matter no navy to-day can afford to be wanting. A division should, if possible, furnish a company of infantry, except the master's division; and the company should be commanded by the division officer, one of the junior officers of the division being associated with him. In small ships this may not be at all times possible, but when unable to do so, the engineer's division would be merged in the powder division. The high-powered breech-loading rifle and rapid-firing cannon worked by small gun's crews must necessitate an increase in the number of men, and greater intelligence in the powder divisions of our ships, if they are to be efficient; servants and bandsmen will have to be eliminated and better men must take their places: therefore, with a more capable and much larger powder division, one infantry company could be selected from it in large ships. The chief aim must be to have the companies commanded by their own division officers, with whom they are familiar as well as known.

Too much stress cannot be laid upon the fact that the hasty assembling of a naval force for landing, under strange officers to command, can be but ill-advised. Officers should know the men who are to serve under them, and this can only be accomplished by organizing the force under the officers of the ships to which the men belong and to whom they are known. The commander of the naval

brigade and his staff could come from any station or ship, but the company officers should come with the men from the same vessel. A writer on the naval expedition to the Isthmus of Panama in April, 1885, complains of the difficulty encountered under the present system of transfer papers in the selection of good men to fill ratings, especially in an emergency such as the hurried fitting out of an expedition. It will be seen that this difficulty can be avoided by landing men under command of the officers of their own ships. For another writer on the same subject, speaking of the landing of the naval brigade of the North Atlantic Squadron at Gardiner's Bay in August, 1884, with officers and men from the same vessels, says: "It was noticeable that the sergeants and corporals chosen from the *petty officers* and *leading men* performed their duties with intelligence and force. Another fact was apparent: the men who were most distinguished as *seamen* were, as a rule, more prompt and exact in their duties on shore."

In every ship's battalion of two companies of infantry and one company of artillery there should be allowed four ammunition passers and carriers, four pioneers—composed of one blacksmith, one armorer, one carpenter, and one fireman—two stretchermen, one bugler, and two signalmen, with a bayman allowed to the medical officer. On drill days two markers and one drummer will land with the battalion; markers and drummers are of no use whatever in actual service, and should not be taken.

The officers of the ship's battalion would be as follows:

An officer (the Executive) to command battalion.
Company officers.
Adjutant.
Commissary, who will also act as Quartermaster.
Surgeon.
Gunner, with large battalions.
A Junior Officer, when Gunner is not allowed.

The commanding officer of the naval brigade should do his utmost to obtain a band; nothing adds so much to the pleasure of the men, nor aids more to make them contented and cheerful. The band should be armed with rifles and drilled; there are too many non-combatants on shipboard at the present day, and the sooner an effort is made to do away with this state of affairs the better for the service.

I unhesitatingly say that the powder division, engineer's force, music, and all servants, except perhaps the stewards and cooks, should be drilled in the use of the rifle; more particularly in the firings, loadings, and facings. A company of artillery should consist of 16 men, and the men selected for the pieces should come from the larger pivot guns or master's division; preferably the first four men from the latter, if they are accustomed to work and fight these guns on shipboard. The divisional officers from the pivot guns command the sections, junior officers the pieces.

The landing of artillery should generally be limited to the 3-inch breech-loading rifle, the Hotchkiss revolving cannon, the single barrel Hotchkiss, and the Gatling. Smooth-bore howitzers have had their day and they should not be landed. The guns should be manned by large crews, capable of taking with them plenty of ammunition. Too many guns should not be landed, as they hinder the movements of a force and are always a heavy burden. A naval brigade that is thoroughly organized and trained needs but few pieces of artillery. It can be said that we have arrived at that state in the Navy when we are unable to say just how many pieces of artillery should be landed. It would seem far better to land a few guns with large crews and plenty of ammunition; care being taken to keep similar guns together, so as to avoid confusion with the ammunition. Ammunition boxes and wagons should be painted the same color as the gun carriages and limbers, and they should also be numbered. It must be remembered in landing artillery that the nature of the service will always be a great consideration, as well as the difficulties to be encountered in transportation of ammunition for the rapid-firing cannon. All the artillery should have limbers, when 7 additional men would be added to each of the gun's crew, making a crew up to 23 men for gun and limber.

By reducing the number of guns and increasing the number of men in the crews, adding limbers to each gun to carry the large amount of ammunition now required, more efficiency will be gained, and about the same number of men would be landed in a ship's battalion. In small ships one piece of artillery should be landed with the battalion, in the larger ones two pieces. In combining the battalions of a fleet and forming the brigade, more guns would be found than necessary; but as the crews of two guns combined form one company, they could be landed as such if desired, from those ships that would under ordinary circumstances land two pieces of artillery with limbers.

The ordnance manual already requires that the crews of the howitzers and machine guns shall be united so as to form an infantry company and be drilled as such. At the present time, vessels in our service do not land men often enough as infantry. More arms should be supplied to vessels, and one company be selected from each of the powder and engineer's divisions in large ships, and in small ships one company from the two divisions combined. Then in a vessel of the Atlanta class we would have from the crew 2 companies, 92 men, and two guns and limbers, 46 men, 4 pioneers, 4 ammunition passers and carriers, 2 stretchermen, 2 signalmen, and 1 bayman, in all 151, out of a complement of 242 men, not including the marine guard, which would probably land 37 men, making a total of 188. After landing so large a number of men from a vessel of the Atlanta class, there would be left on board 3 men belonging to the marine guard, 26 men belonging to the main battery, 13 men belonging to the secondary battery, and 52 men belonging to the powder and engineer's division combined, total 94 men; a force, with the modern improvements on ships, still large enough to fight and work the vessel. One company of infantry would come from the main battery, one company from the powder and engineer's division combined, and two companies of artillery from the secondary battery, the men from the secondary battery being accustomed to work the machine guns.

The landing of so many men may be considered an innovation on the practice of the service, but it will be seen that the circumstances governing the work required of the ship during the absence of the battalion would decide if all of the force or a certain number of companies should be landed. If the artillery is landed without the limbers, large gun's crews would still be required to carry the ammunition for the machine guns. Still the necessity must be apparent to every one that both the howitzer rifles and machine guns should be fitted with limbers. The men selected to work the machine and rapid-firing guns should be carefully and well drilled, noted for their high standard of intelligence, coolness under fire, and specially alert; the first five men of the crew should be good marksmen, equally well trained. They should be armed and able to defend their guns in the event of a jam occurring in the mechanism and the enemy coming to close quarters. Care should be taken that the ammunition is not separated from the guns, and that guns of the same kind are kept together. Some of the machine guns of the English Naval Brigade in the Soudan failed at the most critical moment, and the failure of

the machine guns in the French army during the Franco-German war was due to the want of men thoroughly trained in their use. The value of the machine gun cannot be overestimated, when it is properly served; and to serve the gun with any degree of success, constant and frequent drills must be carried on and the rapidity of fire determined by practice. Cartridges sometimes hang fire, and in the presence of an enemy, under excitement, fast firing might be a source of great danger; no pains should be spared in the instruction of the seamen in target firing, the most important of all drills in the Navy.

Combining the units, the ships' battalions, and forming the brigade, we would find, say with a force of twenty companies of infantry: ten pieces of artillery, total infantry 880 men; artillery, 230 men; there would be 40 ammunition passers and carriers, 30 pioneers, 25 stretchermen, 10 buglers, 8 signalmen, 1 master-at-arms or 1 ship's corporal, 15 cooks when in encampment, and 3 apothecaries. It will be seen that 10 pioneers have been eliminated in the combination, also 5 baymen and 12 signalmen. These men could be drawn from to fill vacancies, or be used to carry camp equipage, ammunition, and handling rations and stores, the signalmen leaving their kits behind; or they could be turned over to the beach-master at the landing place of the brigade.

The apothecaries and stretchermen, and they alone, are to care for the sick and wounded; and it must be impressed on the minds of the men that they are never to leave the ranks in battle to assist the wounded. Apothecaries, baymen and stretchermen, with the medical officers, are the non-combatants. Two medical officers should be allowed to the brigade, one being on the staff. An officer should be detailed as signal officer. One gunner would have charge of the ammunition for the infantry, and another of the ammunition for the artillery. A gunner or gunner's mate should be sent with every ship's battalion when landed. The gunner's mates, pack animals, ammunition, and ammunition carts, if provided, should all be under the command of a capable and energetic commissioned officer. Pioneers on the field of battle will assist the ammunition passers, and when the supply of ammunition is exhausted, both they and the ammunition passers and carriers should be ordered to take a rifle and cartridges from any wounded men and join the fighting line. To fill casualties among the ammunition passers and carriers, their places should be filled by men selected from the companies to which they belong. Two carpenters should be detailed with the pioneers.

Marines.—The legitimate duties of the marine corps being those that pertain to soldiering, their organization, equipment and tactics should be all that can be desired. The guards of most vessels being of necessity very small, the combination of two or more is required to form an infantry company, which should be, if possible, numerically the same as a company of seamen. Signal being made, the different guards would be organized into companies with their officers on convenient ships of the assembled fleet, and landed in separate boats pulled by sailors. The companies of marines should be as near like the companies of seamen in their organization as circumstances will permit. Allowing 5 companies of marines in a brigade of total 25 companies of infantry, the 10 pioneers that have been eliminated in the combination could be detailed as ammunition passers and carriers, and 5 baymen as stretchermen.

The total force of marines—5 companies—would be 220 men rank and file, 10 ammunition passers and carriers, 5 stretchermen and 5 buglers.

Officers.—One officer of suitable rank to command battalion.

Adjutant.
One Aide.
Five Captains of companies.
Five Lieutenants of companies.

Intelligence Staff.—Much attention should be given to obtaining information of the movements, plans, and the number of the enemy. To obtain all possible information without the enemy being aware of the fact is a great point gained in actual warfare.

An Intelligence Staff, selected, if desired, from the intelligence officers of the fleet, should land with the brigade. When an expedition is fitted out and sails from the United States, this staff could come from the Naval Intelligence Office, Washington. This staff should be composed of two officers with their outfit and necessary assistants, their strength depending very much upon the mission they are to fulfill. They should come under the immediate command of the Adjutant General of the brigade or Chief of Staff. Their duties must not be confounded with the duties of the signal staff, the work of the latter pertaining more to keeping up constant communication between reconnoitering parties and the main body, or between the main body and fleet. No matter how small the force, an intelligence officer should accompany the landing party. The great necessity for

such a staff was shown at Alexandria, Egypt, during the bombardment of that city by the English fleet, 1882, and more particularly after the landing of the English naval brigade.

The frequent preparation of the English landing force for a threatened attack, and unreliable information as to the movements and whereabouts of the enemy, very much crippled their force thrown on shore there to protect the city, costing loss of life and very considerable loss of property by fire.

The Field and Staff Officers of the naval brigade should be as follows:

An officer of suitable rank to command the brigade.
An officer to command each battalion, and one aide.
Brigade Staff.—One Adjutant General (also Chief of Staff).
One Ordnance Officer, who also acts as Military Engineer.
One Quartermaster and Commissary.
One Signal Officer.
One Surgeon.
Two Aides to commander of brigade.
Intelligence Staff.—Two officers.

Sanitary Precautions.—In spite of science and modern inventions to destroy men in battle, the fact still remains that disease carries off more men than all other causes together. No pains should therefore be spared to provide for the proper treatment of the sick and wounded. When not in the presence of an enemy, the first consideration in pitching a camp should be sanitary conditions of the ground.

A code of instructions guarding against prevalent diseases, and emanating from the senior medical officer of the brigade, should be followed as closely as possible. Men should sleep in their shirts and drawers, their shoes, stockings and outer clothing being removed. In throwing up entrenchments and bivouacking on new-made ground, the health of the officers and men will be greatly increased if they have something to sleep on. The ventilation of tents should be carefully attended to and no crowding be permitted. When in encampment, tents should be struck frequently in fine weather to allow the sun to dry the ground occupied by them. No orders preventing men from committing nuisances in camp can be too strict. In entering on an expedition, if possible, such seasons of the year should be selected as will favor the health of the men; and it would be well to bear in

mind the frequent moving of the brigade to new camping grounds. A very liberal supply of medicines and food should be provided for the sick and wounded.

It cannot be doubted for an instant that we are sadly in need of transport vessels for use of both the Army and Navy. After the landing of a naval force from transports, the vessels could be used as a base of supplies and for hospitals.

In the *preparation of orders* for the brigade the following points should be well considered, the commander of the brigade defining the duties and responsibilities of each officer, and his subordinates:

1st. Object of expedition and probable length of time on shore.

2d. Number of each arm of the service, infantry and artillery, to be landed.

3d. Rendezvous for boats.

4th. Map of "order before landing," with the position of each boat and covering vessel marked thereon.

5th. Number of covering vessels.

6th. Name of ordnance vessel, hospital ship, provision ship.

7th. Number of artillery boats to assist to clear beach and not to land.

8th. What articles each boat is to carry.

9th. Number of days' provisions men are to carry.

10th. Number of battalions and by whom commanded.

11th. Officer to command at beach.

12th. Number of rounds of ammunition that each man is to carry.

13th. Amount of spare ammunition required.

14th. The distance of objects on shore from the beach, for use of covering vessels and artillery boats.

15th. Order of formation of the line of battle on shore.

16th. What men are to carry, provisions, ammunition, clothing, etc., and what articles are to be left in the boats.

17th. If spare ammunition, water, stoves, etc., are to be landed from covering vessels or to be kept in boats at landing.

18th. If entrenchments are to be thrown up by beach-master, and if he is to have any of the heavy guns landed for armament.

19th. State of tide, depth of water, and the nature of the bottom.

The commanding officer of the brigade should receive his orders in writing from the admiral, or senior officer present, or when an expedition sails from the United States, from the Secretary of the Navy; but he should not be hampered by instructions and petty details in the former case.

The battalion commanders and the beach-master should receive their orders or instructions from the commander of the brigade, through the chief of staff, or adjutant general, and in no other manner.

II.—Equipment.

The equipment of sailors landed from our ships for operations on shore should not be a matter of individual whim or fancy. There should be no sparing of criticism until we have attained uniformity in the combination of the guns' crews and the battalions of a fleet of vessels meeting even for the first time. The breech-loading magazine rifle, with which every naval brigade should now be equipped, brings before us the problem of the supply of ammunition to the fighting line.

Firings will begin at longer distances, and with the continued advance at the most critical moment the men may be without ammunition; to guard against such a catastrophe will be one of the most difficult services required of us. To meet this requirement a considerable force will be wanted to carry and pass ammunition, which can only be attained by reducing the size of the infantry companies. On an extended march horses and wagons would have to be pressed into service, when the ammunition passers and carriers would make up the ammunition train, converting any wagons obtained into ammunition wagons. A small wagon, fitted for one horse, and also with a drag-rope, the wheels being the same as those for the artillery wagons, should be furnished each ship in the service that would land two companies of infantry and one piece of artillery. This wagon would be used for the transportation of extra ammunition, mess gear or camp equipage. Ammunition passers and carriers will always be a necessity, either to carry ammunition on the march or to supply the fighting line in battle. There appears to be a considerable difference of opinion as to how the naval brigade should be armed, but the weight of authority would seem to favor arming every man with a rifle that could carry one. In the artillery companies the first 7 men of the guns' crews should be armed with large-size navy revolvers of the latest pattern. Cutlasses should be discarded, as they are of no earthly use; the remaining men at the gun should be armed with rifles. Should limbers be landed with guns, 13 men would go with the gun and 10 men with the limber. In fitting limbers for the artillery the wheels should be exactly the same

as those for the gun carriage, being interchangeable; all wheels to have broad treads, that they may be serviceable in sandy and marshy ground. The first 3 men of each limber's crew are to be armed with revolvers and the others with rifles, all rifles to be fitted with slings to go over men's backs. In case of a jam in the mechanism of a piece which would render it liable to be taken by an enemy, the riflemen would be prepared to prevent a capture. By introducing light shields the fighting power of the artillery might be improved. Shields weighing about 5 pounds to the square foot could be fitted to the gun carriages, and admit of easy transportation. Pioneers will be armed with large-size navy revolvers, and carry implements for entrenching and cutting road-ways. Every man armed with a rifle, except men belonging to the artillery, should carry 80 rounds of ammunition. In the artillery the men armed with rifles will carry 40 rounds, and those armed with revolvers 60 rounds of ammunition.

Two orders of marching will be used in this paper, *Light Marching Order* and *Heavy Marching Order*. I have given the amount of ammunition to be carried by the latter; the former would carry half of this amount, as seen in the accompanying tables. These two "marching orders" should be used throughout the service, and the articles to be carried in each should be specified in the orders of the fleet, that it may be known on each ship how her battalion is to be equipped on receiving a signal to land.

Officers should be armed with a sword and revolver—large size—though it may be a question open to discussion if the days of the former are not numbered. The sword as a badge of office may serve its purpose, but for actual war it is a useless appendage. An improved magazine gun fitted with slings, and not too heavy, would be very useful for all officers of companies.

The sword bayonet is too heavy and clumsy; a light, well-made bayonet should be supplied. Cartridge boxes, belts, and pouches for carrying ammunition should have straps to support them from the shoulders; when not supplied, the straps can be made on shipboard of canvas, crossed at the back like suspenders. The handiest belt now in use for carrying cartridges is the Mills web belt, which seems to answer every purpose in the Army, when the one that is worn around the waist is fitted with shoulder straps. Extra belts can be filled with cartridges and packed away in canvas bags to be served out in an emergency. The emergency having passed, they would be turned in again. These extra belts should be worn over the left

shoulder. Every officer and man should carry a blanket; the men's blankets should be rolled in a canvas or waterproof sheet strapped together and slung over the left shoulder and retained there by a loop. Rolled in the blanket should be a woolen shirt, a pair of woolen stockings, and a towel.

There is no reason why men should not be furnished with light canvas knapsacks for carrying blankets and clothing; experience teaches us that without them there is little comfort either in the camp or on the march. Canteens should be carried by every one; if unable to obtain them, common bottles covered with canvas and fitted with slings will carry sufficient drinking water. Every man will carry a mess pan, pot and spoon slung to his belt or in his knapsack.

Ships' sails and the boats' sails make very good tents; capstan bars, boats' masts and oars being used for tent poles. For a prolonged stay on shore, application for tents to be supplied from the Army would be better; though there is no reason why each vessel in the Navy should not carry several tents instead of so many useless and spare sails.

The ammunition passers and carriers should be equipped each with two canvas bags, one worn over each shoulder; the bags containing 100 rounds of ammunition each, and weighing 11 pounds; this would give 22 pounds weight to each carrier. Should no pack animals or carts be available for the spare ammunition, large ammunition bags would be required, each one capable of holding two of the smaller bags—200 rounds. These large bags will be strapped with leather, each strap having two loops or rings, through which should be run poles; the poles should also have wide straps a short distance from the ends to go over the carriers' shoulders, and of the proper length to permit them to be grasped by the hands. The total weight for two men to carry would be 46 pounds (400 rounds of ammunition). Ammunition passers and carriers are not armed. Buglers and signalmen will be armed with rifles fitted with leather slings. Signalmen will also carry kits. All the medical force should wear the red Geneva cross and carry a flag (white with red cross), to be displayed from any field hospital or building that may be in use. None of the force will be armed except the medical officers, who will wear their swords only. The master-at-arms and ship's corporal will be armed with the navy revolver and carry 20 rounds of ammunition each.

Dress.—Officers' dress should be the uniform blouse; underneath the blouse a strap should cross the body, passing over the right

shoulder to support the sword; woolen shirt, blue trousers, and brown leggings fitted with a lacing—buckles are a nuisance.

The head-dress for both officers and men should be the uniform cap, and in hot climates the helmet and canvas hat; a curtain to shade the back of the neck would also be useful. Every one should wear brown leggings that come well above the calf of the leg so that they cannot slip down. White short leggings may look well on drill, but in active service they are liable to slip down when wet, and they also make a good target for the enemy.

The new white canvas hat now issued to the men should be dyed brown for active service on shore. Everybody should have two undershirts and two pairs of socks — underclothing and stockings should be of wool—woolen stockings are indispensable on the march. If necessary, officers should provide themselves with overcoats and the men with pea-coats; and each should have a piece of painted canvas or waterproof sheet to sleep on. When tents are carried, a ship's tarpaulin thrown on the ground makes an admirable bed. When transportation can be obtained, officers' and men's effects could be carried in ship's bags that will keep out the water; one bag to an officer, and one to every three men, the latter messing and sleeping together.

Officers and men should bear in mind that any white articles of dress are conspicuous marks and are sure to draw the fire of an enemy's riflemen.

The brigade commander and staff should be mounted, if horses are obtainable, as also the commanding officers of battalions and staff. When the brigade is under fire all mounted officers would dismount.

Gun-cotton or some kindred explosive should be supplied to ships, and issued to the landing force for the purpose of blowing up buildings, furnished in 20 or 25 pound kegs, with outfit for firing. In the defense of buildings, or of an entrenched position hastily taken on landing—anticipating an attack—by placing several kegs of explosive material at the points most likely to be assailed, great assistance would be given to the defense. Gun-cotton was used with good effect at Alexandria, Egypt, by the English naval brigade to destroy buildings and prevent the spread of the terrible conflagration that raged after the bombardment of that city in July, 1882; while the attempt of the American fleet to land powder in tanks and carry it through the streets with burning buildings on either side was not a success — in point of fact, the attempt was abandoned.

Armed Cars.—It may frequently occur that armed railroad cars can be made use of by landing parties, such as flat cars fitted for carrying light guns, with boiler plates and sand bags for the protection of the crews.

When a force is landed to occupy a city, or no march is contemplated, 100 rounds of ammunition should be carried by the infantry, and 80 rounds of revolver ammunition by the artillery.

Weight of Articles carried by Men.

Infantry.

Light Marching Order.

	Pounds.	Ounces.
Waist-belt, bayonet and scabbard	3	12½
40 cartridges	3	14
Rifle (Lee magazine, long barrel)	9	
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¼
Pot, spoon, pan, knife	1	4
Blanket roll, containing one undershirt, soap, towel, comb, one pair stockings	4	11½
Tobacco		3?
Total	33	1
Articles worn by Infantry (weight)	7	8

Heavy Marching Order.

	Pounds.	Ounces.
Waist-belt, bayonet and scabbard	3	12½
One belt, over left shoulder	1	
80 cartridges	7	12
Rifle (Lee magazine, long barrel)	9	
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¼
Pot, spoon, pan, knife	1	4
Blanket, rubber poncho, towel, soap, comb, one undershirt, one pair stockings, pea-coat	11	13¼
Knapsack	2	2½
Tobacco		3?
Total	47	3¼
Articles worn (weight)	7	8

ARTILLERY.

Light Marching Order.

	Pounds.	Ounces.
Waist-belt, revolver and 40 cartridges	4	12
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¾
Pot, spoon, pan, knife	1	4
Blanket roll	4	11½
Accoutrements	2	4
Tobacco		3?
Total	23	6½
Articles worn (weight)	7	8

Heavy Marching Order.

	Pounds.	Ounces.
Waist-belt, revolver and 60 cartridges	5	6
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¾
Pot, spoon, pan, knife	1	4
Blanket, rubber poncho, towel, soap, comb, one undershirt, one pair stockings, pea-coat	11	13¾
Knapsack	2	2½
Tobacco		3?
Total	31	0¾

RIFLEMEN WITH ARTILLERY.

Light Marching Order.

	Pounds.	Ounces.
Waist-belt, 20 cartridges	4	5¾
Rifle (Lee magazine, short barrel)	8	12
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¾
Pot, spoon, pan, knife	1	4
Blanket roll	4	11½
Tobacco		3?
Total	29	7¾

Heavy Marching Order.

	Pounds.	Ounces.
Waist-belt, 40 cartridges	6	4¾
Rifle (Lee magazine, short barrel)	8	12
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¾
Pot, spoon, pan, knife	1	4
Blanket, rubber poncho, etc.	11	13¾
Knapsack	2	2½
Tobacco		3?
Total	40	11

Thirteen men of each artillery company are armed with rifles, but without bayonets.

One hundred men would require the following rations for two days on shore: a total of 465 pounds 10 ounces, divided as follows, each man carrying 1 pound of pork, cooked, 1 pound of beef, cooked, 2 pounds of bread, 4 ounces of sugar, 2½ ounces of coffee, 4 ounces of beans, cooked. Total, 4 pounds 10½ ounces per man.

Strength of a naval brigade of 20 companies and 10 pieces of artillery:

1 Brigade commander.
Infantry—12 Field and staff officers.
40 Officers of companies.
1 Passed Assistant Surgeon.
1 Gunner.
2 Carpenters.
880 Rank and file.
40 Ammunition passers and carriers.
30 Pioneers.
25 Stretchermen.
10 Buglers.
8 Signalmen.
1 Master-at-arms, or
1 Ship's corporal.
3 Apothecaries.

One officer to command at place of landing of brigade called Beach-master, with three officers to command the divisions of boats at landing.

The master-at-arms or ship's corporal will have charge of all the mess outfit and one mess kettle for each company.

Artillery, 10 guns—4 Field and staff officers.
5 Officers of sections.
10 Junior officers.
1 Gunner.
230 Men.

Should no limbers be supplied, the crews would be reduced to 16 men for each piece of artillery, making a total of 160. In this event the other men, 7 in number, from each crew would be required to carry ammunition.

Pioneers will be armed and equipped as follows (Light Marching Order):

	Pounds.	Ounces.
Waist-belt, revolver, 40 cartridges	4	12
Haversack, two days' rations	5	15¼
Canteen, filled	4	4¼
Pot, spoon, pan, knife	1	4
Blanket, roll	4	11½
Tobacco		3?
Intrenching tools, bag of miscellaneous implements	13	
Total	34	2½

For Heavy Marching Order add 9 pounds 14¼ ounces.

Pickaxe, spade or shovel, crowbar, axe and saw should all be slung, if possible, over men's backs, also the bag of implements. Each armorer will carry an axe, weight 4 pounds, and a leather pouch or bag containing assembling and repairing tools and any spare parts for small arms—weight of bag 9 pounds.

Stretchermen will carry the following (Light Marching Order):

	Pounds.	Ounces.
Haversack, two days' rations	5	15¼
Canteen, filled	4	4¼
Pot, spoon, pan, knife	1	4
Blanket, roll	4	11½
Tobacco		3?
Outfit, supplies, etc	6 to 18	
Total	34	6½

For Heavy Marching Order add 9 pounds 4¼ ounces.

Buglers and *Signalmen:*

	Pounds.	Ounces.
Waist-belt, 20 cartridges	4	4¼
Rifle	8	12
Haversack, two days' rations	5	15¼
Canteen, filled	4	4¼
Pot, spoon, pan, knife	1	4
Blanket, roll	4	11½
Tobacco		3?
*Signal kit	5	7
Total	34	13¼

For Heavy Marching Order add 11 pounds 8½ ounces.

* *Buglers* would carry bugle instead of signal kit. Buglers and signalmen are not armed with a bayonet.

MARINES.

The arms and ammunition of the marines should be the same as furnished to the seamen—the latest improved magazine gun. The arm now furnished to the marine corps is a pattern of bygone days, also the cartridge box. Why this well-trained corps should be so armed and equipped ought to be a question for immediate consideration. The marines should wear brown leggings, and their helmets should be brown or dark gray in color, for service in the field; white belts should be discarded for active service. The arms for the marines should have dark leather slings attached, and each man should carry 80 rounds of ammunition, except when landed for short service, when 100 rounds per man should be carried and the Mills web belt used.

WEIGHT OF ARTICLES CARRIED.

Light Marching Order.

	Pounds.	Ounces.
Rifle (Lee magazine, long barrel)	9	
Waist-belt, bayonet and scabbard	3	12½
40 cartridges	3	14
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¼
Pot, spoon, pan, knife	1	4
Knapsack, containing one undershirt, soap, towel, comb, one pair stockings, blanket (wool)	8	10
Tobacco		3?
Total	36	15½

Heavy Marching Order.

	Pounds.	Ounces.
Rifle (Lee magazine, long barrel)	9	
Waist-belt, bayonet and scabbard	3	12½
One belt over left shoulder	1	
80 cartridges	7	12
Haversack and two days' rations	5	15¾
Canteen, filled	4	4¼
Pot, spoon, pan, knife	1	4
Knapsack	2	2½
Two blankets, wool and rubber, towel, soap, comb, one undershirt, one pair stockings, overcoat	14	8¼
Tobacco		3?
Total	49	14¾

Here I want to emphasize the importance of frequently landing the brigade fully equipped. When the brigade is encamped for drill

and instruction, cooks will be sent from ships, and they will be under charge of the master-at-arms or the ship's corporal.

Rations.

The quality of the U. S. Navy regulation ration as now served out on ships is excellent. It frequently happens that there is not time to cook food on shipboard when the landing party is called away, and once on shore it may not be possible to go into camp at meal times. Some form of food like the Bologna sausage should therefore be added to the ration, and put up in packages for landing parties. The Navy ration as now put up is in too large packages which are not easily handled. When articles are served out to a small number of men there is great waste.

Articles like pork, beef, beans, sugar, rice, etc., should be put up in ¼ and ½ barrels. Other articles of the ration should be put up in small boxes that one man could handle easily, marked "Landing Party," and kept ready for issue. The greatest care must be given to the drinking water, and when the water is bad, weak cold tea or coffee should be carried in the canteen. At these times an extra allowance of tea or coffee should be served out to the brigade, the former being preferable in hot climates.

III.—Tactics.

The conditions of modern warfare having changed the movements of troops in actual battle, we must eliminate from the infantry tactics everything that is not suited to these modern conditions. There is a great cry at the present time for an immediate change in our tactics. It would appear that there are not so many changes demanded by the modern conditions of war, but that a confusion of terms has arisen in the application of the words *tactics* and *science*. Infantry tacticians seem to be of one accord that extended formations are necessary, and that night attacks will be more common, if we would provide against the destructive effects of an enemy's magazine rifles. Instead of masses marching in close formation, a loose order of fighting will have to be adopted, the aim being individual action, with all working to gain a common end. The axioms of the day are that "troops once engaged they cannot be relieved, and they must always be rallied to the front." I will not attempt to go into the much-vexed question of the hour, how to close with your enemy without being so

badly cut to pieces or so depleted by losses that any attempts to charge him would be idiotic; the greatest military writers of the day have failed to solve this question, and it is one that pertains more to the science of war. The first line of battle being formed by the skirmishers pushing forward, the supports would be gradually absorbed by this first line, when the main body of infantry and artillery would advance.

It is questionable if much is gained, except when advancing on a strongly entrenched position, by what has been so frequently advocated in the past few years, advancing by rushes. Running heats the blood and makes the nerves unsteady; firing under these conditions is a waste of ammunition and encourages the enemy. When advancing on the enemy, good marksmanship is sought after, and with running the conditions are unfavorable.

At Tel-el-Kebir the English Royal Marines advanced by rushes, and, as a result, were beaten into the enemy's works by another battalion that never stopped after once taking up the rapid advance, carrying everything with them.* It is impossible to lay down a positive rule; we must be governed by circumstances and the capabilities of the enemy.

The sailor possesses some of the highest of the qualities required by the tactics of the present day, and we should train him to develop these qualities to the utmost degree. Stiffness and regularity of movement are in direct contrast with his every-day life, and only that part of the manual of arms which would be required on the field of battle should be taught to him. Of what use is "Present arms," "Reverse arms," "Rest on arms," etc.? It is a waste of valuable time to teach these movements to the seaman. The "Position of the soldier" and "Setting up" drill, found in Upton's Tactics—and this would probably apply to any tactics—should not be imposed upon the seaman. It is simply absurd to talk to the sailor about "the little finger behind the seam of the trousers"; too great precision and uniformity of movement should not be required. When not marching, pieces should be invariably at an "order," and any order for a forward movement would be the signal to bring them to a "carry." All facings should be done with pieces at an "order," and thus avoid tiring the men with their constant weight. In moving to the attack, pieces should be brought to the position of "Arms port," a convenient position to take the "Ready" from, the piece and arms at the same

* Gen. Sir Edw. B. Hamley, in the *Nineteenth Century*.

time affording a considerable protection to the body. The position of the piece at "Arms port," in company or platoon front for clearing streets and forcing back a mob, is in common use; but it is a mistaken idea to use gentle measures when dealing with mobs. Nothing takes the nerve out of the proverbially cowardly mob so quick as the bayonet. The "Level trail" with the arms hanging naturally, so much used in England, is a very convenient way to carry the rifle while marching in column. Marching in line, the rear rank will open out one pace.

It is almost impossible for a sailor to learn so many bugle calls in the short time devoted to infantry drill; even the officers do not acquire them. "Advance," "Retreat," "Halt," "Fire," "Load," "Cease firing," "Assemble," "Charge," are all that are required; and they should be sounded frequently, that the men may be made accustomed to them. Ships' boats might be named "Advance," "Retreat," etc., and called away by bugle with these names. Should a boat be wanted while at general quarters, the boatswain's whistle would be used and the boat called away by name.

I am an advocate of the whistle for company officers. On the skirmish line it would be indispensable; and as the calls are very easily acquired and familiar to the sailor, the whistle or boatswain's call would serve the purpose better than the bugle. All pieces should have dark leather slings and the men should be accustomed to their use when firing.

In Upton's Tactics we should do away in the manual with "Present arms," "Secure arms," "Rest on arms," "Reverse arms," and "Support arms." "Carry arms" should take the place of "Present arms" in saluting. The heavy infantry "support" should be used, as it is adapted to the bolt-gun, which has no projecting hammer. At the order "Halt," when marching under arms, pieces should be brought to an "order arms" without further delay.

The strict drill of the soldier has for its object the disciplining of the men, that implicit obedience to orders may at all times be expected and obtained. The sailor having therefore been educated up to this implicit obedience on that most excellent parade-ground, the quarterdeck, why devote further time to his discipline at the risk of breaking his spirit of independence, which is now so much sought after in the new school of fighting men demanded by the open fighting formation. Better to teach men to be marksmen with no instruction in tactics, than to have a dress-parade sailor with no idea how to

load and fire his piece, not to mention sighting at an object 500 yards away.

I have attempted to enumerate some of the changes in the manual of arms that would benefit the brigade under our present system of training. The adoption by the Navy of the U. S. Army Tactics, of whatever system it may be, will always be a necessary consequence; but the manual for the Navy must be suited to the arm, as well as to the sailor; the tactics for both Army and Navy being the same. Slight changes in the manual as at present given us in Upton's Tactics could be made with much good resulting therefrom; but these changes should be closely followed by every ship in the service, all adhering to the same drill. Marching in company front and the attempt to imitate the solid wall may receive the applause of the public; but to gain such results, what a sacrifice of valuable time that should have been devoted first to the loadings and firings, and second to the skirmish drill! Constant drilling of the company with small intervals between files, sighting and firing the piece, with the expenditure of plenty of small arm ammunition at target practice, is a necessity that must be apparent to all.

In deploying the modern fighting line, Upton's Tactics under the head of "To deploy the battalion as skirmishers by numbers," the battalion being in line, commends itself. To deploy from column, a certain number (specified) of companies would move to the right front into line, and a certain number (specified) to the left front into line. The deployment of infantry on the march from column should of course be carried out before the fire of the enemy's artillery has begun to tell on the ranks.

Under the present system of musketry instruction, the Navy has no field-firing to speak of, particularly when men are attached to sea-going ships. The time has come for an immediate change, not only that the naval brigade may be efficient, but that riflemen stationed in the tops and about ships' decks in battle may fire with accuracy. In this particular we could take pattern from the Army and have more rifle-range firing. Seamen are supplied with as good fire-arms as science can produce; but however excellent these arms may be, in the hands of unskilled marksmen no effective work can be performed. The men should be taught at the different Receiving Ships, both in rifle and machine gun firing.

If the time devoted to cleaning bright-work on shipboard were taken up in teaching the crew aiming drill and file-firing exercise, we

would have more efficient marksmen in the service, and necessarily more effective crews. Bright-work should be painted out, covered with canvas, or anything to get rid of it in a ship—its cost is not a subject for this paper.

Any unseemly haste to rush through the small-arm target practice in cruising ships is absolutely indefensible. And though we are much in want of a system of rifle range practice with small arms, still it lies in the power of a commander of a fleet to send his battalions ashore to compete for prizes and medals at the range when he assembles the vessels for their annual drills and inspections. At these contests, individual competition should be paramount and the marksmen be encouraged in their work.

In seagoing ships the officer of the deck in the afternoon watch should be relieved by a junior, when he would drill his company in the loadings and firings with the dummy cartridges. Cartridge boxes or belts should be filled and several rounds fired, to ascertain just what the men are capable of doing. On an examination of the pieces and the boxes or belts after each ten or fifteen rounds fired, and before the dummies are gathered from the deck by the quarter-gunner, the effectiveness of the firing drill would be known. This would not only accustom the men to be expert in the loadings and firings, but familiarize them with the breech mechanism of the piece. The rough usage to which the mechanism of all breech-loading firearms is subjected in service on shore calls for special attention to its care if the arms are to be kept in a serviceable condition. Arms and ammunition should be examined very frequently. Officers and men should be made familiar with all the parts of the magazine guns, and understand which parts are most likely to be rendered unserviceable. The men should be thoroughly taught the working of the breech mechanism, and when landed in the brigade, should frequently examine the gun and ammunition to see if the parts of the former are in good working order and that the ammunition is clean and fit for use. On fitting out an expedition, great pains should be taken to examine the ammunition, to see that it will fit the arms for which it is supplied. It cannot be too strongly impressed on the minds of drill officers that all drills not fitting the seaman for battle should be abolished, the manual should be the simplest possible and adapted to the requirements of the service.

When we realize it is claimed that the modern arm in the hands of fairly drilled men requires the discharge from it of nearly twice the

mean weight of a man in lead before it effects his death, we cannot be too careful in our firing instructions. In firing, if any control is to be obtained over a command, the order "five rounds" or "ten rounds rapid fire" should be used. Under the head of fire discipline, I quote from General Von Kraft of the German army, who is authority on this important subject: "I have often remarked how much fire discipline is weakened in action when the element of danger makes itself sensible. Troops imperfectly trained do not aim, they do not even fire, they only let off their pieces. . . . . But how much more trouble is required before we can train the infantry soldier to pay attention to orders and signals during all the excitement of battle, to observe the object to be aimed at, the sight and mode of firing to be used, and to cease firing when the specified number of rounds has been expended. . . . . But if, as we have remarked, soldiers must already attain to a certain pitch of fire discipline before you can be sure of getting them even to bring their rifles to the shoulder in battle, how much greater pains must be taken before you can get them to take aim. . . . . When firing once begins men get easily out of hand unless restrained by an iron discipline. . . . . It is but human nature that a soldier should derive some comfort from the noise made by his own gun when it goes off. The more raw the soldier the more will he be inclined to 'shoot himself into courage.' . . . . Taking such facts into consideration, we cannot help doubting whether the order 'Five rounds rapid fire' when given at close quarters, say 300 yards, will be attended to."

The Elementary Light Artillery Tactics as now taught at the Naval School, Annapolis, and generally throughout the service, appear to be all that is desired. The men should not carry bayonets and cutlasses, and the drill should be completed for the gun with limber, and the crew increased to 23 men, if we would guard against the new dangers to which artillery is exposed by the development of rifle fire and the difficulties encountered in the supply of ammunition. In the *Elementary Tactics* we must confine ourselves to one system of drills—and there are many good systems—for all the service, eliminating everything not tending to efficiency on the field of battle. The modern conditions of war demand that for *Grand Tactics* the movements of guns in battle must be at a "double." This fact is supported by the field movements in action of European artillery, which require the guns to be moved by horses at a run. By doing away with cutlasses and bayonets, the former being liable to get between

the men's legs, not to speak of the extra weight and general uselessness of both, the guns' crews are as near flying-light as it is possible to make them, and at the same time they retain their efficiency, care being taken not to bring guns into action without infantry supports *in advance*.

Wishing to emphasize what has been said before, I would again call attention to the necessity of simple and effective drills in both the artillery and infantry, and the avoidance of *ceremonies* that belong to the parade-soldier. As little time as possible should be devoted to dress parades.

The Disembarkation and Landing of the Naval Brigade.

In the disembarkation of the brigade great care and attention should be given to the boat organization. Each company of infantry (seamen) should land in the two ships' boats belonging to the division of which the company forms a part; being at all times accustomed to go in these boats, there will be no confusion. The larger boat will be in charge of the captain of the company—the lieutenant of the division—a junior officer of the division being in charge of the smaller boat. These two boats must always keep together, the larger one being on the right, and in forming the "order before landing," must take the same relative position in the line as the company holds in the brigade when formed on the beach.

The rifle howitzers and machine guns will go in the heavy boats. Three or four hammocks placed in the bows of boats, about the pedestal for the revolving cannon, would be a great protection to the crews of the guns in action. The marines will land in separate boats pulled by sailors, the latter being detailed from companies belonging to the reserve; though, with a system of boat drill in this corps, the marines could in a short time manage their own boats. A company of marines with their officers should be assigned to two boats, the boats keeping together.

The boat divisions in the "order before landing" will be commanded by the battalion commanders, each battalion forming one division of boats. The senior officer's boat of each division should have a mast, from which signals should be made and repeated; and should also carry signal books, spyglass, and a box containing medical supplies and outfit. Each boat must be provided with a signal book and answering pennant.

Each division of boats should have a distinguishing flag, and each boat should be numbered in the "order before landing" from right to left consecutively, 1, 2, 3, etc., commencing on the right of the skirmishing boats down the line, then to the right of the main body down that line, and the same way with the reserve and hospital boats. The artillery boats should be lettered from right to left, A, B, C, etc., to distinguish them from the other boats. Boats should have their numbers and letters painted on canvas, large size, and nailed to the stern and both bows; if possible, the numbers of the same color as the divisional flags. Each boat must carry an anchor and chain or rope, and in landing the boats must anchor by the stern, going ashore bows first.

It adds considerably to the comfort of a landing party if they can get on shore dry-shod, and to do this gang-boards could be carried slung over the gunwales of the boats underneath the oars; spare pieces of lumber found on shipboard and the carpenter's bench could be utilized for this purpose. Each boat should carry a bucket for bailing, materials for stopping shot holes, and a breaker of water. Intrenching tools, rope ladders, etc., should also be distributed among boats. Boats will carry their own ammunition. Spare ammunition and extra belts for the infantry will be carried in boxes—it might be more convenient to carry the latter in canvas bags. Empty powder tanks carried in boats make good magazines for the storage of ammunition when it is put up in canvas bags. The amount of ammunition will depend upon the nature of the service.

Before undertaking an expedition, proper means for the transportation of ammunition supplies, camp equipage, etc., should be provided by the quartermaster. Improvised means of transportation with carts made on shipboard should be the last resort, for they seldom answer the purpose required of them. Life rafts, or temporary rafts, are very convenient for landing, and a great assistance in getting ammunition and supplies on shore. No pains should be spared to land men and outfit dry.

If transportation is to be obtained and a lengthened stay on shore is to be made in encampment, boats should carry stoves, one for every two companies of infantry or four companies of artillery; also two scouse kettles and four mess kettles, sails and spars for tents, provisions and water.

It must be borne in mind that the nature of the service to be performed governs the preparations of the naval brigade. The more distant the service from the base of supplies, and the longer the

stay, the more the brigade must be governed in its movements by the rules laid down for a brigade of infantry; and those who would study this interesting subject are referred to that admirable work, "The Soldier's Pocket-Book," by Lieutenant General Sir G. J. Wolseley.

The light-draft vessels should anchor near beach to protect the landing, and also act as a base for supplies. They should keep as near to landing party during the time the force is on shore as the depth of water will permit, one vessel being used for the ordnance boat and another for provisions and hospital. Several of the vessels that are to cover landing should be provided with electric search lights. Should the landing be made in the night time it would be well to have three covering vessels with search lights, one on either flank and the other behind the centre of the "order before landing." These vessels would keep out of the effective range of shore batteries, or move about, altering their range and position frequently. They would light up the beach with their electric lights, and the landing force would approach the shore in the dark zones between the lights, so as not to be seen by the enemy. The brigade once landed, the search lights would be used to light up the country in the direction of the enemy, and good lookouts stationed aloft would report any suspicious movements, when signal would be made to the force on shore.

In forming the "order before landing" (see Plate I.) each boat should take the station assigned it in the organization; the presumption is that every officer has been made acquainted with all the details of the organization both before and after landing. When the distance to the shore is great, boats should be towed to a convenient place from the landing and out of range. The boats mounting the heavier guns of the artillery will be on the extreme flanks of the "order before landing," and next to them the light guns; all the artillery boats in echelon formation, with the main body of the infantry between. Two boats' length in advance of the centre of the main body of infantry, the skirmishers in light fast boats should be massed, with a few machine guns on the flanks, if desired.

The skirmishers, generally speaking, would be taken from the companies of marines. The reserve will be in the third line in rear of main body, and it would consist of about one-sixth of whole force; they are not to land until main body is well established on shore and has moved back from the beach. The hospital boats will be three boats' lengths in rear of centre of main body of infantry. These

boats will be pulled by the stretchermen, and they should be light single banked boats, containing medical officers and outfit, flying the hospital flag. Hospital boats will land with the main body of infantry, under charge of the medical officers and under orders of the chief of staff. The first line—skirmishers—should be two boats' lengths apart. The second line, main body, two boats' lengths in rear of skirmishers and one boat's length apart. The third line, reserve, three boats' lengths in rear of main body and one boat's length apart. The hospital boats in rear of centre of main body three boats' lengths, and in pairs one boat's length apart. If there should be opposition to the landing of the brigade, the beach would be cleared by the covering vessels and artillery, and in the event of a heavy fire being directed on the boats it may be necessary to open out the "order before landing" and land on a more extended front. Signal being made by the commander of the brigade, the skirmishers will pull in and land, deploying as soon as landed, taking advantage of such shelter as the ground may offer, after which, signal would be made for main body to land with light machine guns, followed by rest of artillery. The main body having advanced from the beach, the reserve would land.

If it be not the intention that the brigade should remain on shore, any length of time, the landing once effected, to the larger boats with artillery four boat-keepers will be allowed, and to the smaller ones two boat-keepers. The boat-keepers will have their boats out to their anchors after landing, turning the boats' bows out with stern lines to the beach, one man remaining in each boat to veer in when ordered. The boat-keepers are in excess of the number of men allowed to each company. All the artillery boats should be prepared to mount and fight their guns in the sterns of boats, though this might not be possible with the steam launches.

Each division of boats should be careful to keep together in their assigned places with the division flag displayed, one of the boats in each division displaying the flag from its mast. Always being prepared to embark under fire of an enemy, each division of boats will be under charge of an officer, with an officer selected to command on the beach, styled beach-master. The beach-master will have charge of all the boats and force left at the beach, and he will see that the boats are in readiness to embark all the brigade at a moment's notice. He will keep up communication by signal or otherwise with the covering vessels, and if possible with the main force. Such precautions as seizing any commanding position and throwing up breastworks

would be performed by the beach-master. To prevent surprise, he should throw out a picket, and when circumstances require it, a squad of petty officers should be added to his force.

The preparations for embarking having been carefully attended to, on the approach of the brigade the boats will drop in near the beach. If the brigade is pursued by the enemy, entrenchments thrown up by the beach party will be manned, and a few pieces of artillery will be left with the infantry to keep back the enemy. While the main portion of the brigade is embarking, the covering vessels and artillery will keep up a cross fire on the beach until all the force has embarked, the skirmishers being the last to leave the beach.

In the disembarkation, many points come under consideration which require much thought and experience; such as the amount of opposition to be met with from the enemy on landing, the nature of the country, length and character of beach, depth of water and state of the tide. A low, broad, convex beach affords the safest place for the brigade to land, if opposition is to be met with from the enemy. If possible to obtain a chart of the landing place, no disembarkation should be made without one. This chart should show depth of water, character of bottom, and time of high and low water. Each commanding officer of a division or battalion and the beach-master should have a copy of this chart, with the *state of the tide* marked on it for the *time* of landing. It should also show the "order before landing" of the boats and the position of the covering vessels.

Marines.—The tactics of the marine corps being the tactics adopted for the United States army, the marines would assemble with the seamen in the brigade, with no confusion to the latter. The manual of the corps should be the same as that taught to the seamen in all their drills and service with the naval brigade; uniformity in the brigade must be sought after and obtained, and the smaller factor must give way.

All the officers and men of the marine corps should be instructed in the handling of machine guns both afloat and ashore. At the present time the marines suffer for want of experience at the rifle range. They are not landed as often as they should be for instruction in target practice and open-order fighting. If capable of pulling their own boats, they would be independent in their transportation to and from ships.

Marches.—When no opposition has been made to the landing of the naval brigade, a reconnoissance must be made to ascertain the

whereabouts of the enemy, the nature of the reconnoissance depending on the kind of information desired.

If proper care has been taken in fitting out the expedition, charts of the country will have been supplied, with cities, towns, villages, direction of roads, streams, etc., and any high land marked on them, also a weather map and almanac to date. These charts would, if it were possible, have been prepared by the Bureau of Intelligence at Washington, otherwise by the commander of the expedition. Some idea of the country, its inhabitants, the wet and dry seasons, food, animals, etc., must first be obtained before an advance is made into the interior. The commander of the expedition will decide how the march is to be taken up, bearing in mind that a large force divided into two columns will march faster than in single column and with less fatigue to the men. It is also more easily deployed into line of battle; the maxim is, "separate for marching, unite for battle." In the formation of the order of march, guns and ammunition should be so placed in the column or columns that, upon falling in with the enemy, they would be in such position where most likely to be wanted. The time required to come up with the enemy would determine the formation of the order of march. Assuming that you are within striking distance of the enemy, and that a fight with him may take place at any time, care must be taken that each column has an advance guard and is in constant readiness for battle, and that the columns are strong enough to take care of themselves, and are within supporting distance. Artillery must never march alone, nor be left unsupported by infantry. Signalmen must accompany the advance guard. A flank patrol would also be necessary, and communication must be kept up between it and the main column. See Plate II., Figs. 1, 2.

At night, the advance guard, unexpectedly falling in with the enemy, must attack him immediately; there is nothing else left to do if the main column is to gain time for preparation. If necessary, the men and officers must sacrifice their lives, for upon the stand that the advance guard makes, the fate of the main column may depend. If forced back, under no circumstances must they retreat on the main column, but must retire on either side, unmasking its front.

Marches in retreat.—In retreat, the order of march is the reverse of that in advance, the rear guard being much stronger, and from one-fourth to one-third of the whole force, depending upon circumstances.

Street fighting.—In the occupation of towns and cities, street fighting will always play a prominent part in the work required of the naval brigade, and too much time and attention cannot be devoted to its study. A map of the place to be occupied, showing principal streets, squares and public buildings, should be obtained. Having determined upon a plan of operation, move in two or three columns toward the central portion of the place, and occupy a prominent square where the people are in the habit of congregating. Columns should keep up lateral communication with each other, and a body of pioneers should precede each, supplied with gun-cotton or other portable explosive for blowing down doors, buildings and barricades. A column meeting with barricades should not attempt to carry them in front if time will permit of their being turned by working to their rear through adjoining buildings. Advantage should be taken of any flat-roofed houses in working a column through a city. The advancing columns should be closely followed by the supports; surrounded by burning and falling buildings, with firing in every direction, men become bewildered and hesitating if they are not well supported.

In the advance, do not leave burning buildings in your rear if they threaten to cut off your line of retreat. Your forces once established, look to the water supply, and seize any fire engines. The engines should be overhauled and put in order by the force of firemen from the pioneers that accompany the expedition.

If you are fighting to obtain possession of a city, seize all food supplies; all the inhabitants that remain in the city should be enrolled and set to work, and everybody put on the same allowance of food. Arrest any one found on the streets between sunset and sunrise. Establish a signal station on highest building near to headquarters, or at headquarters if within signal distance of fleet. No officer or man should be allowed on the streets without arms or equipments. Keep open your line of retreat, but do not forget that a small force of determined men can keep at bay, in a well-barricaded building, many times their number; in fact, do not allow yourself to be burnt out and you can stay until relief comes, provided your food holds out. Remember the history of the Pittsburg labor riots of 1877 and the cooped-up militia in the engine-house of the Pennsylvania Railroad.*

Should your object be to quell a riot or insurrection, establish your headquarters at the town or city hall; place yourself in communication

*"The United Service," Vol. I., Pittsburg Riots.

with the civil authorities; organize a police force, or lend all aid in your power to the regular force of the place. Barricade and be prepared to defend building or buildings in which your forces are located; two buildings commanding each other are better than one. Never, under any circumstances, permit more than two-thirds of your force to be absent from headquarters on patrol or other duty. If you take any prisoners, do not confine them in your headquarters. Never permit any strangers to inspect your preparations for defense. Arrest any one found looting; impress upon the minds of your officers and men that no property of any kind must be taken; everything that is found must be turned in to the quartermaster. There is nothing so demoralizing to a naval force as to allow men to appropriate articles; the very severest punishment must be inflicted for looting, if any discipline is to be maintained. Sentries should be placed over all buildings near to headquarters where liquors are stored; and above all things, never locate a command in any building without first making a careful inspection to ascertain if there are any spirituous liquors stored therein.

Bivouac.—Plate III. illustrates the general principles of bivouacing with outposts thrown out in the direction of the enemy; when necessary, the flanks and rear would also be protected. The general rule is that about one-sixth of the whole force should be employed on outpost work—the most important duty devolving upon the brigade.

As it takes a very considerable time to break out of tents and strike them, they would not be used in the presence of an enemy or when anticipating an attack.

The German system of outposts is probably the best and most simple. Some 400 paces to the front of the first line, double sentries are placed—this is the only distance given; the other distances, the reserve from the first line, also from main column, are at the option of the commanding officer of the outposts, he being governed by the "general state of affairs and the time the main body requires to get ready for action." In locating the outposts it would be well to remember that one officer should command on each front of the camp; by this means any confusion in the location of the outposts is avoided. The officer commanding the outpost should belong to the command to which the detail for outpost duty also belongs.

Camping (Encampment, Plate IV.).—In selecting a site for laying out a camp, when not in the presence of an enemy, we must

consider sanitary conditions, nature of the ground with regard to the comfort of the men, and the supply of wood and water. An abundance of fire-wood and plenty of fresh water near at hand make any locality a desirable one. The form of the camp will generally be suited to the ground, both artillery and infantry camping on ground best suited to them. In going into camp, each battalion of the brigade would encamp in column of divisions, the tents of each division facing each other, being arranged in two lines and trenched. As far as practicable a general alignment should be preserved, though regularity should not be sought after over more important considerations. The commanding officer of the brigade, also the battalion commanders, should have distinguishing flags on flagstaffs to indicate their headquarters.

In encampment the routine is established by the commander of the brigade, due regard being given to the season of the year.

Camp routine, when brigade is landed for drill and instruction:

h. m.

A. M.—4.00—Call cooks.
5.00—Call bugler of guard.
5.10—Assembly of buglers.
5.15—Bugles and drum march through camp.
5.25—Reveille, assembly, coffee.
6.30—Breakfast.
7.15—Sick call, fatigue call, police camp.
8.00—First sergeant's call, morning reports.
8.30—Drill call.
11.00—Recall from drill.
11.30—Assembly, guard mounting.
12.00—Dinner.

P. M.—1.00—Drill call.
2.00—Serve out provisions.
3.00—Recall from drill.
5.00—Battalions form.
5.15—Brigade forms for dress parade.
5.45—Supper, sundown retreat, orders, details for day following.
8.45—Assembly of buglers.
8.50—Bugles and drum march through camp.
9.00—Tattoo, assembly.
9.15—Bugles, lights out.

To Arms is the signal of alarm, when the brigade will turn out under arms. The *general* is the signal to break camp, preparatory to marching.

Base.—The base of operations of the naval brigade is an important consideration that presents itself to us. Under most circumstances the fleet would be the base, but in operating on rivers and streams, some of the fighting vessels of the fleet with a despatch boat should accompany the boats to be used as a base, if the depth of water will allow. Should the water be shallow, steam launches, armed with Hotchkiss revolving cannon and the single barrel Hotchkiss, with temporary protection for their crews, should accompany the landing force. These launches would not land, and should have large crews, every man in the boat being armed with the magazine rifle, which should be kept at hand ready for use when occasion demanded. Vessels and steam launches accompanying the brigade should, if possible, keep up communication with the force and be prepared to furnish anything necessity required. Accompanying vessels should have large supplies of provisions, ammunition and medical outfit.

In conclusion, the essayist has endeavored to avoid the common fault of the day, when treating of a professional subject, of dealing in generalities. In making suggestions he has attempted to name something better, and solve, with useful details, where he has condemned. To condemn the practices of the service without working out and presenting in detailed form something more worthy of trial, is to remain at a standstill and fail of the purpose sought.

There is nothing in this essay that the writer claims as new and untried; were he to do so, it might detract from its value. Having consulted every work within his reach published on the subject of Naval Brigades, and they are not many, he has summarized and placed the information obtained, with his own experience added, in such shape that he hopes it may supply a long and growing want, benefit the service at large, and be of *practical use* to the brigade commander. Taking hold of a practical subject, the essayist has attempted a practical solution, avoiding any digressions to new-hatched thoughts which would add length to the essay with no beneficial results. Being a great believer in the naval brigade and its valuable work, he would at the same time jealously guard the seaman from the machinations of the infantry-crank and toy-soldier, always keeping in mind the *materia circa quam* of a navy.

INDEX.

Advance guard, 335.
Armed cars, 319.
Articles, weight of, carried by marines, 323.
Articles, weight of, carried by men, 319.
Artillery tactics, 329.
Atlanta, landing party from the, 310.
Bags, ammunition, 317.
Band, 308.
Base, 339.
Battalion organization, 308.
Battalion, ship's, 306.
Beach-master, 333.
Belts, cartridge, 316.
Bivouac, 337.
Boat, organization, 332.
Brigade, composed of, 311.
Camping, 337.
Camp routine, 338.
Company, artillery, 309.
Company, infantry, 307.
Conclusion, 339.
Disembarkation of brigade, 330.
Dress, 317.
Embarkation, 334.
Encampment, 338.
Equipment, 315.
Field and staff officers, brigade, 313.
Firing instructions, 328.
Firings, 327.
Flank patrol, 335.
Gun-cotton, 318.
Heavy marching order, 316, 319.
Intelligence staff, 312.
Isthmus of Panama, 305, 308.
Landing of brigade, 330.
Light marching order, 316, 319.
Machine guns, 311.
Manual, infantry, 325.
Marches of brigade, advance, 334.
" " retreat, 335.
Marines, 312, 323, 334.
Medical force, 317.
Naval brigade, Egypt, 305.
" " Panama, 305.
" " Sfax, 306.
Officers, arms of, 316.
Officers, ship's battalion, 308.
Order before landing, 332.
Order of march, 334.
Orders to commander of brigade, 314.
Orders, preparatory, by brigade commander, 314.
Organization, 304.
Plate I. "Order before landing," reference to, 332.
Plate II. Order of march, reference to, 335.
Plate III. Bivouac, reference to, 337.
Plate IV. Encampment, reference to, 337.
Rations, 324.
Rations, weight of, 321.
Riots, 336.
Routine, 338.
Sanitary precautions, 313.
Street fighting, 336.
Strength of brigade, 321.
Tactics, 324.
Transports, 314.
Von Kraft, General, 329.
Wagon, ammunition, 315.
Weight of articles carried by marines, 323.
Weight of articles carried by men, 319.
Weight of rations (100 men), 321.
Wolseley, Gen. Sir G. J., 332.

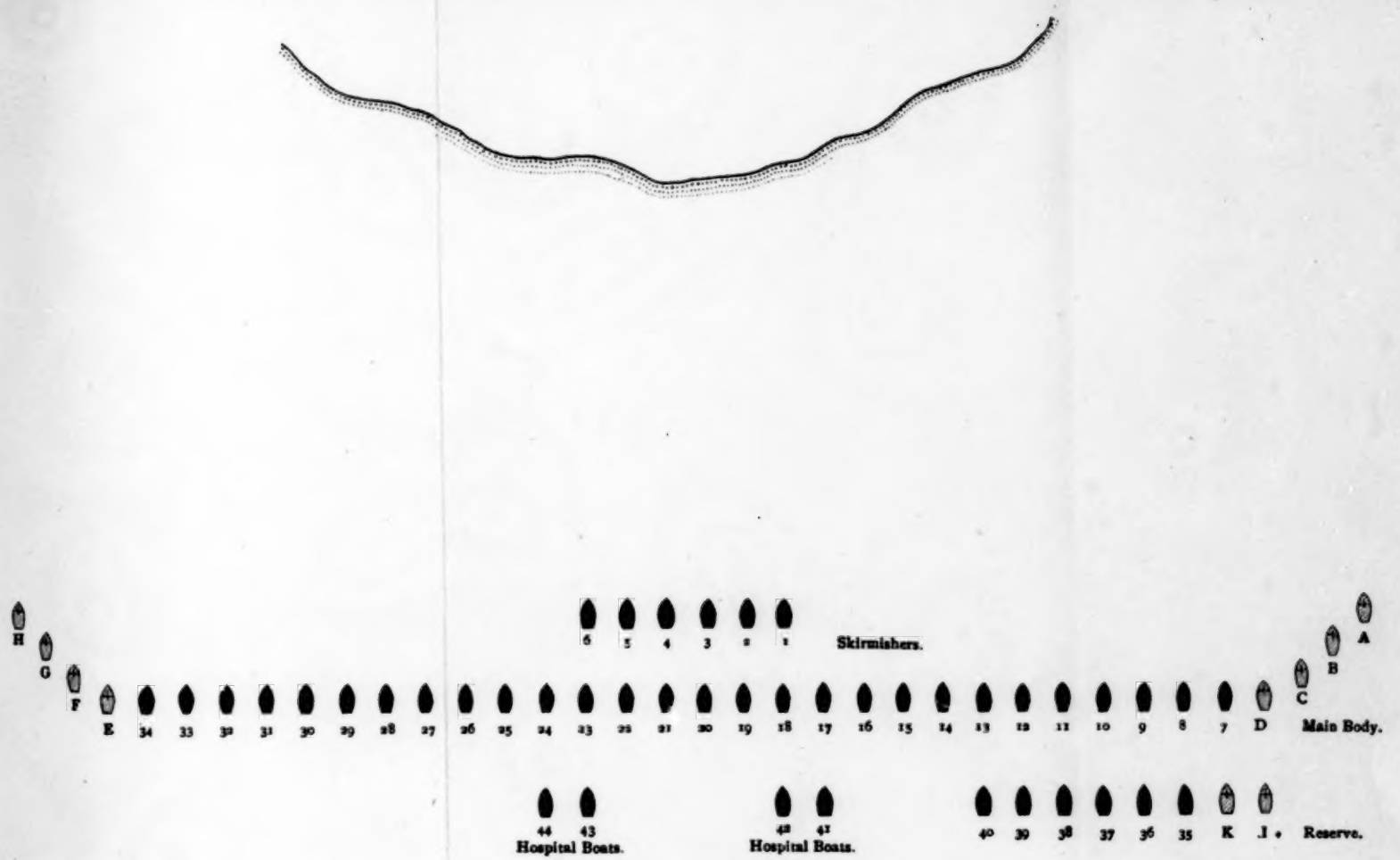


PLATE I. - ORDER BEFORE LANDING.

Skirmishers, two boats' length apart.
Main body, Reserve and Hospital boats, one boat's length.
Skirmishers' boats from Main body, two boats' length.
Main body from Reserve, three boats' length.
Artillery on flanks of Main body, in échelon.
Reserve, about ⅓ of whole force.

Fig. 1.

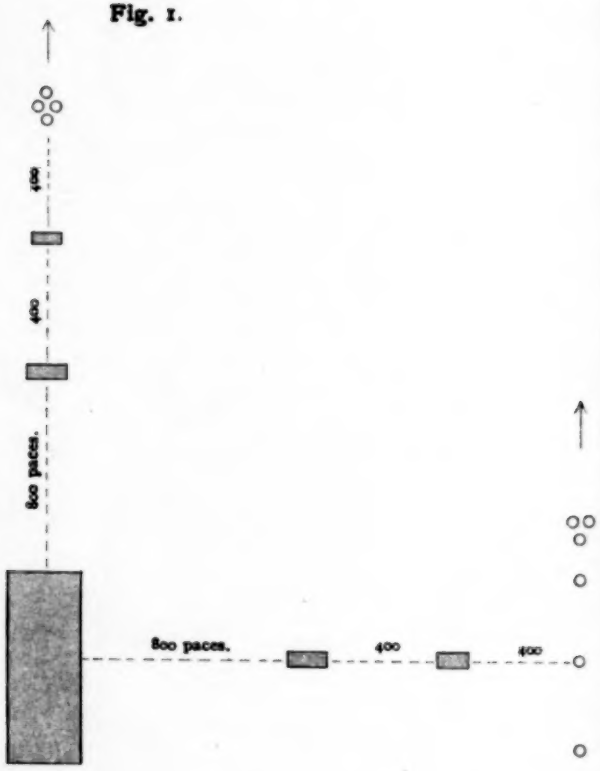
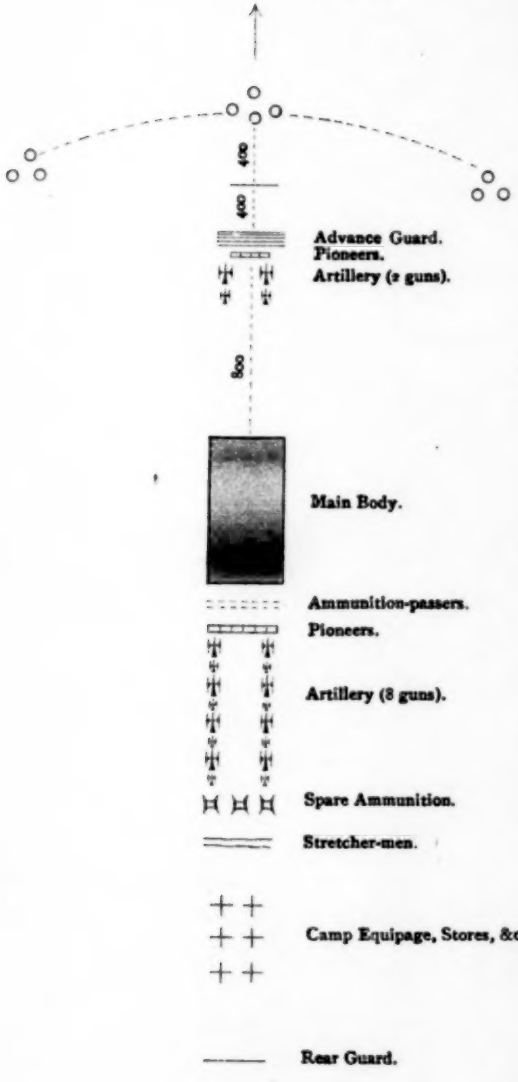


PLATE II. – ORDE

Distances are

Fig. 2.

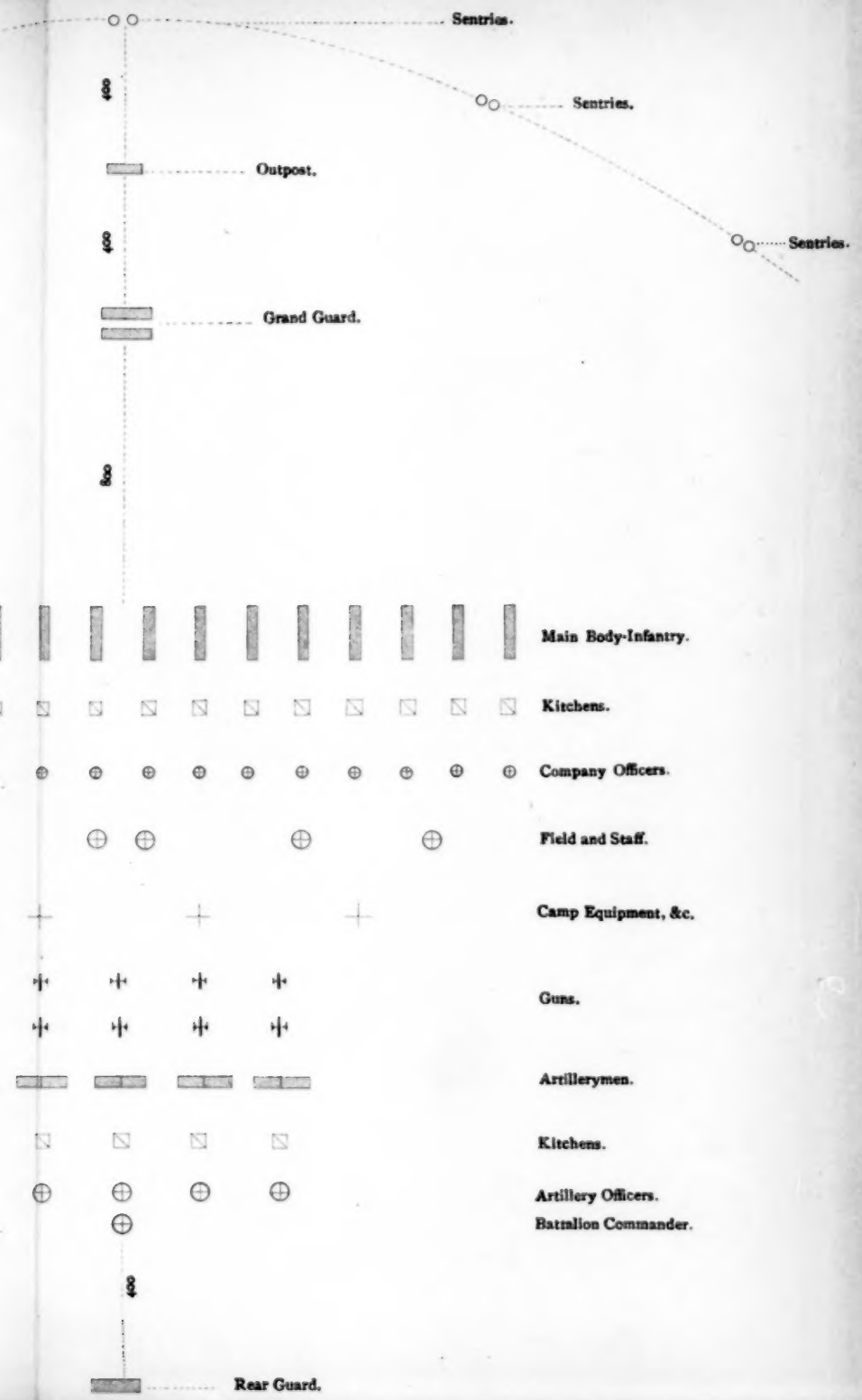


ORDER OF MARCH.

ances are in paces.

Plate III.—BIVOUAC.

Twenty Companies of Infantry, 10 pieces of Artillery, with outpost thrown out in the direction of the enemy.
Distances are in paces.


Sentries.
Sentries.
Outpost.
Sentries.
Grand Guard.
Main Body-Infantry.
Kitchens.
Company Officers.
Field and Staff.
Camp Equipment, &c.
Guns.
Artillerymen.
Kitchens.
Artillery Officers.
Battalion Commander.
Rear Guard.

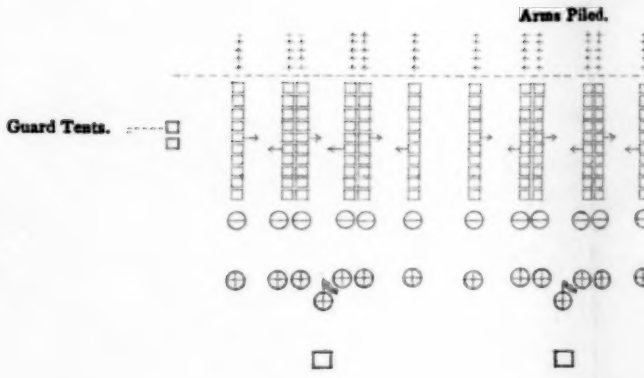


PLATE IV.- ENCAMPMENT OF NAVAL BRIGADE.

Twenty Companies and Ten pieces of Artillery.

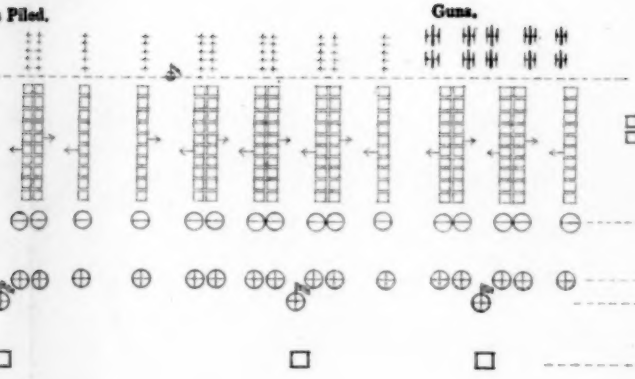
Rear Guard.

□□ Guard Tents.

Men's Sinks.

Piled.

Guns.



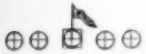
□□ Guard Tents.

Company Kitchens.

Company Officers.

Battalion Commanders.

Officers' Kitchens.



Brigade Commander, Staff.

Baggage and Stores.

Officers' Sinks.

□□ Guard Tents.

[COPYRIGHTED.]

U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

APRIL 27, 1887.

CAPTAIN A. R. YATES, U. S. N., in the Chair.

TRAINING OF ENLISTED MEN OF THE ENGINEER'S FORCE.

BY PASSED-ASSISTANT ENGINEER W. M. PARKS, U. S. N.

The engine department of a modern war vessel may be compared to a machine shop. This comparison holds as well when the engines are in motion as when repairs are making to the main engines, or to the many auxiliary engines used. To get the best results in either case, there should be a force of trained workmen working under competent supervision. There should be a superintendent; there should be foremen or leading men; there should be journeymen, and there should be a certain number of unskilled laborers. In this scheme we may regard the engineer officer in charge as the superintendent. The machinists, men who have served regular apprenticeships, we may regard as the foremen. Following the natural order, the firemen or stokers should be the journeymen, while the coal-heavers form the laborer class.

Unfortunately for us, the firemen—men who should be the journeymen according to our scheme, men who form the majority of the engineer's force—are, as a rule, unskilled in the use of tools and untrained in the rudiments of the art of stoking. The object of this paper is to make a plea for the training of these men; to insist that they shall serve a short apprenticeship, at least, before they are sent to our ships to attempt the work of journeymen. What would be the result if, in a machine shop, only laborers and apprentices were employed? In our war vessels the engineer's force is largely made up of laborers and apprentices. The small number of skilled men, the machinists, can have but little effect upon the mass of the unskilled.

In these days, when it is necessary to have trained men for every one of the various special duties that are found on a war vessel, the fact seems incredible that we neglect to train men for the important duty of properly burning the fuel that is to give power to so many engines. We may continue to design engines that are to be, in theory, the most economical ones possible; but unless we begin now to train the men who handle the shovel, failure will follow every attempt to get, in practice, that power per square foot of grate area that theoretical calculation and the experience of others lead us to believe should be obtained. In our old-fashioned ships, now happily disappearing, the boilers and engines, without much regard to weight or space occupied, are so proportioned that the required horse-power is easily obtained, no matter how wastefully the fuel is burned. In these old ships natural draught is the rule, and from four to six I. H.-P. is required from each square foot of grate surface. Now, however, we see the beginning of a new Navy, with modern machinery, high pressures of steam, forced draught, and the never-settled problem of obtaining the greatest I. H.-P. per square foot of grate. All these changed conditions demand changes in methods.

Look at a few examples showing the need of a trained fire-room force. The boilers and engines of the U. S. S. Atlanta are certainly large enough and heavy enough to furnish 3500 I. H.-P. Her machinery is of an approved and well-tried type, and the method of getting the forced draught is one that has been successfully tried, and yet we have not succeeded in getting the very moderate number of nine I. H.-P. per square foot of grate that the contract requires of that machinery. I say "very moderate number," because, to mention a few examples, the machinery of the English ironclad Colossus has developed eleven and one-half I. H.-P. per square foot of grate area; that of the Impérieuse, fifteen; that of the Howe and of the Satellite, each over sixteen; while twenty I. H.-P. per square foot of grate is expected from the machinery of the Nile. All of these vessels, of course, use forced draught. Surely no one will deny that we need trained men for the fire room, men who will be able to get the greatest power possible out of each pound of coal burned. Remember that we have not yet obtained nine I. H.-P. per square foot of grate with the Atlanta's machinery, and have barely obtained eight and one-third I. H.-P. per square foot of grate with the Dolphin's machinery. These are moderate requirements. From the machinery of the Baltimore we must get double or nearly double the foregoing

proportions, if the required power is to be obtained. A trained dockyard force will get this power, but with our present force of untrained stokers that power will never again be approached. We certainly need a trained dockyard force for power trials; but we need, and pressingly need, a system of training for all the enlisted men of the engineer's force. Much of the plan that I shall propose is not new.

Without going into details, the central idea of my scheme is that all enlisted men of the engineer's force shall have as thorough a training as may be possible in stoking all kinds of coal used in the furnaces of marine boilers, under the conditions of forced and of natural draught, and shall be taught to do the ordinary work of the engine and fire room, under competent supervision; this instruction to be given before the man is sent to a cruising ship. We should thus have in time a body of trained workmen, men who would work intelligently, whether stoking or overhauling machinery, and the engineer officer in charge would be relieved from the necessity of pointing out the exact spot in a furnace where each shovelful of coal should go, or of consuming valuable time to show an inexperienced man how to hold a wrench.

To begin, the apprentice system should apply to the engineer's force. A certain proportion of the boys enlisted on the Minnesota should be kept there to receive instruction by engineer officers detailed for that purpose. The boys should be taught how to handle tools, how to pack stuffing-boxes, to do rough blacksmithing, and to take down and to put together parts of machinery. They should be made familiar with machinery; and, above all, they should be taught the almost lost art, in our Navy, of the stoker. When we get steam training ships, as now seems probable we shall do, the instruction of the engineer apprentices should be continued by their instructors. Practical instruction in stoking with forced draught would be possible. In time we should be able to get all our trained workmen for the two great branches of the service from the same source—the training squadron.

As an extension of this system of training, such of the boys as show marked ability should be sent to the machine shop of some navy yard and required to serve a regular apprenticeship. From this class the machinists of the Navy should be recruited. While serving their apprenticeship in the machine shop, these boys would still be under the instruction of an engineer officer. They could live on the receiving ship at that yard. On the training ships a system of

instruction should be established having rewards for the least coal used to obtain required results, or rewards for taking down and putting up machinery in the least time and in the best manner.

For our present most pressing needs, every receiving ship should be a training school. These schools are ready for the pupils, for on nearly all of them there is machinery, antiquated no doubt, but yet affording a field for instruction in handling the ordinary tools used on shipboard, and for practical lessons in stoking. There should be two engineer officers on every receiving ship designated as a recruiting station for firemen. There should be two receiving ships so designated, one at Norfolk and the other at Boston. The engineer officers detailed as recruiting officers and as instructors should be responsible for the proper training of the men enlisted by them. All men presenting themselves for enlistment as firemen should, after the examination now required, and after enlistment, be given instruction in stoking and in handling the ordinary tools found on board ship. With our present short term of enlistment, three months is probably all the time that can be allowed for this training. The men should be divided into classes, all those enlisting in a month forming a class. The great object to be aimed at in this three months' course is to make the men put coal in a furnace intelligently, and to make them handy in the use of tools required in the ordinary repair-work of the engine and fire room.

There should be but one class of firemen in the Navy, with a uniform rate of pay, that of the present first-class firemen. The firemen should not be recruited from the coal-heavers, unless it is impossible to get qualified men from the training squadron or from the receiving ships. At the end of a cruise, such coal-heavers as have shown fitness and aptitude should have their discharges so worded that they could readily enlist as firemen at the proper recruiting station, and then get the benefit of the three months' training.

DISCUSSION.

THE CHAIRMAN.—*Gentlemen:*—We meet this afternoon to discuss the subject of P. A. Engineer Parks' paper on training enlisted men for the engineer force of the Navy. It is a very important subject, and one that is growing more and more important as the Navy is being increased with modern men-of-war. Machinery is used to such an extent on the lately constructed naval vessels that to the efficient working of ship and battery some mechanical knowledge is as essential for the seamen as for the firemen.

How this knowledge is to be imparted, what inducements are to be offered to the apprentice or enlisted man to become a skilled mechanic, or even an efficient fireman or stoker, are matters involving an acquaintance with the enlisted man's surroundings, inclinations and aspirations.

To exchange our views on this important subject is carrying out one of the objects which the Naval Institute is designed to encourage. Those who have thought much upon the subject, and those who have not, will no doubt receive, from a discussion of the paper before us, ideas that may lead to a definite and efficient plan.

With this aim in view, I trust each one will indulge in a free and liberal expression of his views.

Lieutenant E. K. MOORE.—*Mr. Chairman and Gentlemen:*—The subject before the meeting is certainly a very important one, and I think we all realize the necessity of trained firemen and machinists for our new ships. The present state of our merchant marine is such that I doubt very much if we could get the number we would require from that source.

The subject is one about which I have not thought enough to wish to put myself on record. However, I take issue with the author on one point, and that is, the selecting of a certain number of the apprentices who enlist on the Minnesota and retaining them for apprenticeship in the fire room. In lieu of that I would suggest that the boys be sent on board the training ships, and when qualified for transfer from those training ships, that they be sent to some school, on shore or afloat, for their apprenticeship as firemen, machinists, or whatever other billet they may choose in the engineer force. In the first place, the boy, or any one else who goes to sea, must have a naval training before he can be capable of doing anything useful on board ship. If the boy was trained and taught the different parts of the ship, how to row, how to swim, how to take proper care of himself, of his clothes, bag and hammock, and, besides this, a certain amount of seamanship, ordnance and soldiering, he would then require no more instruction on board ship except in the one professional branch which he might select or be selected for in the future. If he could then be sent to a steamship to serve his apprenticeship, I think it would be better than to take him as a green boy from the street or farm or whatever other place he may come from, and place him at once in the fire room.

Again, I do not think it a good idea to teach apprentices for the fire room on the steam apprentice ships. In the first place, if we have steam on the

apprentice ship it will only be auxiliary, and the machinery will be entirely different from that on any other ship in which he might afterwards serve. The training he would get on the auxiliary steamship would, for instance, be of little use on the Boston, Atlanta, or other new ship. In addition to this, we already have too much to teach the apprentice in the short time that he is allowed to remain on the training ship.

The Minnesota, Franklin, and Wabash are ships of the old type, but might be used for the first part of the training of firemen-apprentices. Then when far enough advanced they could be sent to cruising vessels having boilers and engines of more modern type, there to complete their education and serve out their terms of enlistment. From those that have served their apprenticeship as firemen might be selected a certain number to be re-enlisted as apprentice machinists and distributed amongst the different Navy Yards, to work in the machine shops and on the engines and boilers of vessels fitting for sea. In this way they would get a knowledge not only of the handling of tools, but also of the engines they might be called upon to run in future. Being enlisted, they would not be liable to be laid off on account of want of funds, but would be an addition to the regular force.

Lieutenant J. B. MURDOCK.—*Mr. Chairman and Gentlemen:*—I have not given the subject much consideration, but there are one or two points suggested to me by the paper and by what has just been said. I fully approve of the training proposed, but differ with the author as to the method of carrying it out.

The great need of the service to-day is a higher technical training to fit the men for their duties on board our new vessels. A new class of men is called for on deck as well as in the engine room, and the service would be greatly benefited if the training squadron could supply the latter as well as the former. Owing to the comparatively small number of men allowed the new vessels, the men of the engineer's force will probably have to take part in landing parties, and are, indeed, even now required to be instructed in small arms and machine gun drill. It will be a great advantage if they are given a systematic training, and are subjected to the habits of discipline in which apprentices are educated in the training ships.

I am decidedly opposed to the idea of educating the engineer apprentices on the Minnesota in New York harbor. If the steam training ships which the Chief of the Bureau of Equipment and Recruiting has been requesting are ever built, the natural place to educate boys for fire-room work will be on board those vessels at sea. In that case, let each boy take his turn at stoking, as well as at instruction in seamanship and ordnance, and if any develop peculiar fitness for the work, let greater facilities be afforded them.

I do not think, however, that every boy developing mechanical skill or ingenuity should be assigned to the engineer's force. Machinery is being introduced into every part of our new ships, and a knowledge of tools is very necessary on deck also.

I wish to call attention to the fact that at present the pay of first-class fire-

man, the only class provided for in the paper, is the same as that of chief boatswain's mate, and this will naturally attract men to the engineer's force, leaving an inferior class on deck to perform duties requiring at least equal skill and knowledge. Our modern training must fit men for the greatly changed conditions of our new vessels; and, if necessary, somewhat of the present training should be left out, as we cannot expect to make our apprentices "Jacks of all trades."

Ensign DENFELD.—*Mr. Chairman and Gentlemen:*—The work in the fire room is too hard and too confining for those who have not reached their full growth. By training boys in the fire room there will grow up an inferior class of men who cannot be depended upon in emergencies. A few years ago the system of training boys in the Navy for the engineer's force was given up after a short trial. There was a marked difference in physical appearance between the fire-room boys and those on deck.

It is very essential that a course of training should be given to the men who enter the engineer's force—for a period of one year, let us say. During this time enough military and technical training can be given to fit men for the routine work on board a man-of-war. At most of the shore stations the necessary course of training can be given, and it will take only a short time on shipboard for those who have completed it to become masters of the situation.

Commander HIGGINSON.—*Mr. Chairman and Gentlemen:*—I cannot help approving of this idea of educating naval apprentices, because it seems to me we stand much in need of some such system. I think that every boy destined for the Navy should receive at the commencement of his career a military and nautical education, whatever position he may subsequently be called upon to fill, and whether before or abaft the mast. It is only by following this general principle that the efficiency, mobility, and harmony of the service can be maintained. The Naval Academy is doing some good work in this direction, and might with profit extend its sphere of action; and now, in filling the engineer force with trained men, let the training squadron do for the rank and file of the service what the Academy is doing for the officers.

As has been remarked by Mr. Denfeld, the boy destined for the engineer force should be of some growth and maturity, and his earlier years cannot be better employed than on board the training squadron. He will not only acquire there the necessary physique, but he will gain that nautical basis to his education which will enable him always to feel at home upon the sea. Many officers have noted how little general interest in the service is oftentimes found in the engineer force, and this unsympathetic attitude towards their surroundings and associates has presented at times a serious impediment to the complete harmony and discipline of the ship. Now it seems to me that this uncongenial feeling may be eliminated by taking boys from the training squadron and training them for the engineer force. Then not only the officers but the rank and file would be possessed of a sailor's knowledge, and be available for use in case of an emergency.

I think there should be no difficulty as to the details of this scheme, and they should be worked out in harmony with the present system of naval training, and under the same direction. It is only a part of a general system of naval education for boys and should be under one head. The boys may be educated for stokers, firemen, or machinists, according to their capacities or inclinations, and either afloat or ashore as may be found most advantageous. Inasmuch, however, as after his double education he becomes of double value to the Government, his pay, if not double, should be in excess of that of the man who is only educated in one direction. This would be only fair treatment of skilled labor, and would offer an incentive to the boys to undertake the additional training. All boys entering the engineer force should be required to serve for a length of time—not less than ten years—sufficient to reimburse the Government for the education bestowed upon them. It must be remembered that, unlike the sailor, the engineer can find a market for his wares on shore, and it is against such a misuse of benefits conferred that the precautions should be taken.

Lieutenant ROHRER.—*Mr. Chairman and Gentlemen:*—It is admitted by all that a skillful and well-qualified engineer's force is necessary on board our ships. The use of steam and machinery is constantly increasing, and the better trained our firemen and artificers are the more power will they develop from a given amount of coal, and with the least wear and tear of machinery. It would be very satisfactory if we could secure a sufficient number from among the boys who have gone through the course of the present training system, and who have arrived at the requisite physical maturity for further training to qualify them as firemen and artificers. What they have already acquired would of course make them so much more valuable in the new field to which they would be transferred. It is a question in my mind, however, whether the fire and engine rooms offer sufficient attraction and inducement to youths who have qualified as seamen to warrant a hope that the engineer's force could be sufficiently recruited in this way. If it can be done, it were well to do it so.

Supposing it cannot be so recruited, I would suggest a system of apprenticeship to be carried out at all our naval stations where boilers and machinery are in constant use. The youths should be from eighteen to twenty-two years of age, of the necessary strength and robustness to stand the work of our more trying fire rooms. They should be shipped as general engineering force apprentices for five years. They should be thoroughly instructed in firing, in caring for boilers, and in handling and using such tools as they may develop a capacity to use. The brighter and more ambitious should receive special training to qualify them as ship's machinists, coppersmiths, blacksmiths, oilers, water-tenders, and the like. Upon passing prescribed examinations for the various positions which the ambition of each apprentice warrants him to try for, they should be put into the general service with the assurance that they are to have the rates for which they have qualified, when vacancies exist.

It appears to me that a valuable set of men could thus be obtained, though they would not have been set up as soldiers. To attain this end, they could

be quartered upon the receiving ships or barracks at the various stations, and there receive at specified times the military instruction, which certainly is very desirable and important. Or, these apprentices, after a certain time of training on shore at the naval stations, might be transferred to a steam cruiser especially set apart for the purpose, there to finish their training, and then to be transferred to the regular cruising ships. As to the military training of the engineer's force of our ships, I see no reason why the men composing it should not be set up as soldiers while they are waiting on the receiving ships for transfer to the cruisers.

It seems to me that some system like this will provide the force we want; and it can then be recruited from the existing training system, from the merchant marine, and from the farm and street. Take the competent youths from wheresoever they may come, train them at the naval stations upon an elaborated and sensible plan, turn them into the special cruiser and then into the general service, securing to them the higher ratings for which they prove themselves qualified,— this, in brief, is the plan that I would suggest. What I have said will, I hope, be understood simply as a suggestion which may possibly be of use in solving the problem under discussion.

THE CHAIRMAN.—*Gentlemen:*—As I said in my previous remarks, we must consider the enlisted man's surroundings, his inclinations, and his aspirations. To improve the first, we must make them such that he will not only be enabled to live with all possible comfort on board ship, but also in such a manner as to encourage his self-respect and generate a liking for his life. A very great improvement is being accomplished in this respect in his treatment and accommodations. The nearer we approach a satisfactory state in these matters, the greater will be his inclination to remain where he is guaranteed a sure and permanent remuneration for his services and a just and considerate supervision. The exact course to be pursued to attain these results, although germane to the subject of the paper, I will not now undertake to discuss, nor give my views, except to say that the enlisted man, like every other, must have his aspirations for higher place and position considered and whetted, to obtain from him valuable and beneficial results.

The question of obtaining competent machinists and firemen for the service has not, I must say, engrossed so much of my attention as that of obtaining competent naval seamen, for the reason that I have felt that the duties of these men in the service are so similar to those on all modern steamships that a supply could always be obtained, particularly as the pay in the service is tolerably fair, and, except in occasional instances, the work is not arduous.

The question that has given me most concern is what inducements can be offered to a man to become an efficient stoker or fireman. If a plan can be devised by which men can be trained and retained in the service to fill these positions it would certainly be desirable in every respect. Would a young man on board of a man-of-war have the means of making himself a skilled mechanic, so that he could hope to receive the rate of machinist? I think not. This knowledge he must obtain in a machine shop, either ashore or

afloat; and even after he has this knowledge, it is a question whether he will be willing to take a step down and make a cruise as a fireman. The introductory steps to becoming a stoker cannot be taken by a boy. The work requires a full-grown and tolerably strong man, unlike in this respect to the training to be a machinist or seaman, which not only can begin in youth, but it is advisable that it should so begin.

To obtain a supply of firemen and coal-heavers I would propose the following modification of Mr. Parks' plan. On the receiving ships at navy yards enlist men, not under 21 nor over 28 years of age, as firemen and coal-heavers. The qualifications for the former should be a fair knowledge of the duties of the rating, such as is obtained on the ordinary merchant steamer or tug, a common school education, and excellent physical powers. For the coal-heaver, the necessary physical power and a fair character. Have an engineer officer, with the requisite number of machinists, to instruct these men in their duties, affording them all the facilities necessary to this end. There is no doubt but that soon all the receiving ships will be lighted by electricity, and thus an opportunity will be afforded for instructing the firemen in the care of the dynamo and engine.

It would be, in my opinion, an excellent plan to have all the rebuilt monitors of the Miantonomoh class commissioned and stationed in our principal harbors, —one at least at this place,—and to have the firemen, before being drafted, made to go through a short course of instruction on board of them. These vessels could also be used to instruct such apprentices as, having served eighteen months in the training squadron, and shown a fair mechanical ability, may desire to enter the engineer force as machinists. Should naval seamen apprentices, after receiving their discharges on arriving at the age of twenty-one years, desire to enter the engineer force as firemen, they should be given the opportunity to do so, by re-enlisting them under their C. S. C., and instructing them in their duties on the monitors. The great advantage of having men in the engineer force who have received the training of the naval apprentice squadron would add so much to the military character and consequent efficiency of the ship or service that the attending time and expense would be amply returned to the Government.

The plan of educating machinists for the Navy at a navy yard I do not approve. Judging from an experience of three years in one of them, the work is so fitful and uncertain that the apprentices, if retained on the chronic giving out of funds before the end of the fiscal year, are necessarily employed in keeping the shops and machinery in order, and not directly in learning their trade. The Navy will always have to depend in a great measure for its supply of machinists and firemen on the merchant service. If we can leaven the number with some instructed as mentioned, I think we shall be accomplishing about all we can expect or hope for now. England, whose naval training system is probably the most complete in the world, does not, as far as I can ascertain, attempt to train men specially for machinists and firemen. They are doubtless selected from her dockyards and other sources. Commander Chadwick does not mention them in his admirable book on the "Training of Seamen in England

and France." I do not mention this fact as the reason why we should not train our own engineer force, but simply cite the example as showing that the largest navy in the world has not yet been driven to this method of obtaining them. After we have created an adequate supply of trained naval seamen, which is the imperative present need of the service, we shall be better able to strive to create one of machinists and firemen. But until we do furnish a sufficient supply of men for those duties on our men-of-war that cannot be learned elsewhere, further steps than those mentioned I do not think absolutely necessary. We should simply be producing incomplete and unsatisfactory results.

I understand that allowing apprentices to go into the engineer force was tried at one time with good results. An old machinist in the service, now at this station, states that so many wanted to enter the engineer force that the plan had to be given up. That nearly all wanted to go might have been the case, as the pay of firemen is equal to that of the highest seamen petty officers in the Navy—in my opinion a very sad condition of affairs, and one not calculated to obtain and retain the most desirable material for seamen. The pay of the seamen petty officers of the first class should be raised to that of those with whom they rank.

As I have stated in my opening remarks, I have not given this matter the thought I ought, but what I have stated is my opinion at present. Further consideration of the remarks made here, and further reflection, may lead to modifications in my views.

Before adjourning we should thank P. A. Engineer Parks for the interest he has shown and his advocacy of a plan for the improvement of the personnel of the service. It is a healthy indication and one deserving our heartiest co-operation.

The following discussions were received in manuscript from some of those that were unable to be present at the reading of Mr. Parks' paper, but to whom proofs of the paper had been sent with a request for an expression of their views on the subject.

Commodore SCHLEY.—*Mr. Chairman and Gentlemen:*—The paper of P. A. Engineer Parks touching the training of men for the engineer force is in such complete accord with my own views on this subject that I endorse most he has said in his admirable presentation of this great need.

The argument he makes for higher training is supported by the fact that the contrivances employed to obtain high power in our new ships differ so widely from those in common use in our old ships that special training is essential to the men who are to be required to develop this increased power. When it is considered that the new engines are somewhat more complicated in design, quicker in motion, and that boilers differ in form and construction, that higher pressures are to be maintained, that there is a labyrinth of pipes and connections for pumping, that a new system of forced draught is to be employed, that

greater horse power per square foot of grate surface must be obtained, that the conditions of air-tight fire rooms change old requirements, it would seem almost ridiculous to expect untrained men to be of the slightest use in our new vessels like the Baltimore, Charleston, or Newark. As I understand the problem, we have a certain aggregate number of square feet of grate surface upon which to convert coal into energy. In the old ships with natural draught the possible horse power was from four to six. In the new vessels with forced draught there have been developed from eight to sixteen horses, with possibilities up to twenty horses. In other words, with the best picked coal we are to require at least 68 per cent more energy in the same area than ever before to obtain the power that is to accomplish the high speed of the new ships.

It goes almost without saying, that if these results are to be attained our men must be trained. I can conceive no other way to bring this result about; indeed, I think that the only reason for the failure to develop the required horse power of the Dolphin and the Atlanta is that the engineer force of these vessels is untrained to the new system. It is safe to say that each trip of these vessels will indicate improved results growing out of better acquaintance and more training with the new machines. This brings me to the suggestion that unless we train our men before placing them on board of the new ships, we shall be obliged to train them after going on board. This means simply that the new ship, under the latter circumstance, will be for several months unfit for duty, during which time she would be easily whipped by vessels of inferior power manned with a trained force.

I am free to say that I am committed entirely and earnestly to this matter of higher training of men who are to serve us in our new ships, and have intended to commence it as soon as we shall have succeeded in securing the steam training ships advocated since my accession to the Bureau.

With reference to the age at which this training should commence, I must differ with Mr. Parks, for the reason that the work to be done by the person trained requires the fuller physical and mental development of a man. The tendency of fire-room work to develop diseases of the heart in the adult would be a strong reason against training an undeveloped boy to this duty. Again, it would appear that the work to be done demands more strength of body and general intelligence than could be expected from a growing lad who learns rather by imitation than by the immediate exercise of his reasoning powers. No: I would train men of twenty-one years and over with more certainty of success and with less probability of injury to their health.

I have merely thrown these views together in the hope that the discussion to follow may give more light upon this subject, or to invite suggestions from others who may have thought upon it.

Chief Engineer GEO. W. MELVILLE.—*Mr. Chairman and Gentlemen:*—Although agreeing in the main with my brother officer that all men need training for their special duties on board ship, as in fact in all walks of life, I cannot compare the engineer department of a modern man-of-war with that of a well-organized machine shop. In the machine shop, from the superintendent down to the apprentice boy, all things work harmoniously, each having his share

of the work to do, and each man is responsible for the work done. Every mechanic employed is supposed to be able to do his day's work and do it well, misfits or mistakes causing the man's discharge, the apprentices alone being allowed a little latitude, because of the fact that they are the learners. I learned my trade in a machine shop, and if any man engaged as a machinist could not do his work he was discharged, and here ended the matter.

Not so, however, is this the case in a military organization. If a man manages to be shipped in a certain grade, he cannot be disrated without the form of a court-martial. He is not a responsible person with the danger of discharge from lucrative employment before him. In the machine shop—in fact in all manufacturing establishments—everything is done by rule and line. In a man-of-war fire room this cannot be: the fire and engine rooms are a scene of continually changing conditions and expedient. In the modern man-of-war or iron fighting machine—where we have anywhere from 400 to 800 tons of engine and boiler, and the most of it under tension, almost to the breaking point, either from pressure in the boilers or strain on the moving parts of the engine—the conditions are entirely different from that of the machine shop, and both officer and man must be alert to avoid accident, to substitute one part for another, make quick repair in emergencies, or make one system of pipes or valves do service entirely different from what they were intended for. In certain cases the engines must not be permitted to stop, or the battle is lost or won. Not so in the machine shop: when the bell rings, noon or night, all hands quit and go home. To-morrow morning will suffice to continue the construction of the fabric in hand, and if we are hurried we can put on more hands, and discharge them when the hurry is over.

To my mind, the great difficulty with the engineer force is the fact that there are so very few mechanics among them. A man cannot learn the trade of machinist or smith on board a ship of any kind; and because a man becomes familiar with tools or the use of tools in a crude way, he is rated by the officer put over him to the grade of the artisan class, thus spoiling a good, first-class fireman to make a worthless machinist or boilermaker, so-called. And were either out of employment, the last place they would dare to go and ask for employment at either trade would be in a machine or boiler shop. We might as well expect an excellent coachman to be a coachbuilder in any of its multifarious branches.

There are men shipped or rated in our service to-day in the mechanical branches who are totally ignorant of the trades they are supposed to follow, and who cannot do either engine, boiler, or smith work. I mean men who have not learned the trades, and cannot go into a shop on shore and do a job of work.

Mr. Parks may argue, "So much more the reason why we should drill or teach the men their duties." Firing or handling the machinery may be taught on board the ship, but the trades cannot be. And it is to this class of petty officers the engineer officer must look for intelligent aid in handling and repairing and keeping in repair the vast amount of machinery which is daily growing greater and more intricate. The day has gone by when any man who could shovel coal and pack a stuffing-box on a slow-moving, low-pressure

engine of 15 or 20 pounds of steam can be trusted with the high pressures now in vogue, and which are daily increasing. We must have the young, bright, intelligent engineer, who knows his responsibility and danger and can appreciate them, to direct the duller material that does his manual labor and keeps his machinery in repair.

He is required to give confidence to his subordinates by his coolness and intelligent supervision of the moving mass of machinery—not from deck or from his state-room through a speaking-tube: he must be right there among his men, through soot and black, heat and steam. Though he be called ignoble because he soils his hands, if he would be the efficient engineer and serve his Government as he should, he must do all this and more too, and let the pleasure be his that he, too, is a part of the modern fighting machine and the soul that gives it thought and movement. It seems impracticable to me to put men through a course of training for special service on speed trials—except on board of our cruising ships, where they soon get all the training in firing and overhauling the machinery it is possible for them to have—as my experience in the service has been that the men who did the running at sea employed all their time in port overhauling machinery, one ship alone excepted, the Lancaster, which at that time was an auxiliary-powered ship. Selections might be made from the well-known men who are shipped for general service that could be employed for this special duty for steam trials; but where these services are so seldom called for, I doubt if it would be good policy or convenient to hold such a body of men for that service. What would it avail us if we found, by a special force, on experimental trials, that a ship made 16 knots per hour on a coal consumption of 1.6 pounds per H.-P. per hour, if in practice, while cruising, we made but 14 knots and it cost 2.5 pounds of coal per H.-P.? I fear this is a rock on which many persons are splitting. A measured-mile speed trial cooked up and jockeyed for a record is very different from the actual cruising practice, and it is only on these special speed trials when the high speed of ship and economy of engine are shown. When the ship goes out into service, the actual fact of practical running is brought into play; and it is in our service as in all other services, whether naval or merchant marine.

The jockeying for high speed and economy lapses. Steam jackets and special appliances are shut off because they require more care and attention than can be shown them, because of the reduced force on board to attend to them, and the blooded horse with the fire of "Maud S." and her special jockey falls into the traces of the steady-going roadster or dray horse.

Having been attached to the Atlanta, I suppose I should be expected to say something concerning that magnificent ship, so much better than any we have ever had before in our service. We should be proud of her, though some of my fellows differ with me. She has plenty of engine and boiler, and should make 4000 horse power. The cause of her ill-success up to this time has not been alone a want of a trained force so much as a combination of conditions in a new construction, including forced draught, ventilation, arrangement of coal bunkers and bunker passages, and the facilities of working under these new conditions. There are other defects which will be remedied in new construc-

tions, and that will be palliated when she is formally accepted by the Government. Suffice it to say that the Government never before got so much ship for so little money, and the labor this ship has passed through will bring forth good fruit in the new constructions now in hand.

Mr. Parks will naturally ask what I propose instead of his scheme. I too would train men to do their work properly and well; but I would use the force as now enlisted. I would enlist no man in the artisan class unless he was a mechanic who had learned his trade in a properly equipped shop for the fabrication of machinery. I would not promote a man from the fireman class to the artisan class because there was a vacancy, and because he was a good oiler or water tender. I would promote coal-heavers to all grades below that of artisan, for all my experience has shown me that the coal-heaver at the end of a cruise makes the best fireman. He has been trained and drilled, and is still young and vigorous enough to do the duty of a fireman, and he won't last long. He will soon be burnt out, like an old grate bar, and will soon have to drop out to make way for the new material to be recruited from the able-bodied and most intelligent of the coal-heavers.

I would try to make the men happy so far as lay in the power of the commanding officer of the ship, and make them feel that, although black and grimy from heat, soot, and labor, they were part and parcel of the fighting machine; that their labor was honorable if well done, and that they shared in the honors of a well-drilled fighting machine; that they were not damned because they were grimy; and I would never degrade them by clearing the "brig" of its prisoners and roughs and rogues to recruit the fire-room force in an emergency. By recognizing these men and the labor they perform as necessary and essential to the success of the ship, they too would be made to feel that spirit of friendly rivalry that pervades the other parts of the ship, and it would take the weight off their minds that they are the "damned firemen."

Passed-Assistant Engineer A. M. MATTICE.—*Mr. Chairman and Gentlemen:*—I agree most heartily with the author that something must be done in the way of training men for the engineer's force of our prospective ships, but I differ from him in some respects as to what this something should be. In the first place, as great physical endurance is one of the first requisites of a good fireman, I should object to the enlistment of immature apprentice boys, and would offer inducements for men to enter the service who have had some previous experience in hard firing—on locomotives, for instance. They might be enlisted for a short period of probation, say six months, and if at the end of that time they proved acceptable, they could be enlisted for four years. I would have one or two small steamers in constant use, with forced draught, where these men, during their period of probation, could be trained in the working of modern marine boilers. The tugs of the Fortune class might be utilized for this purpose by replacing their present boilers by smaller ones fitted for forced draught. The men should spend the first six months of their long enlistment on board a steam receiving-ship and at a navy yard where they would be instructed in the use of tools.

But to get such men—and we will not be able to get along without them—

inducements must be offered. In the first place, we must give more pay. I know that this will be objected to immediately, as firemen now get more pay than other enlisted men of the same class. But labor is a merchantable article, and will bring what it is worth, and the more we pay, other things being equal, the better article will we get. Moreover, increased pay is not the only inducement which must be offered in order to obtain better firemen, as well as better men of other classes. The condition of the life of enlisted men on board ship must be improved; the fact must be recognized that they are human beings and should be treated as such. Their mode of messing must be made more decent; they should be allowed more leave of absence on shore after their day's work is done, instead of the infrequent "liberty" (most appropriately named) now granted; they should be paid their hard-earned money once a month, instead of having grudgingly doled out to them various pittances under the names of "monthly money," "liberty money," "mess money," etc.; greater precautions should be taken against the awarding of unjust punishments; a practicable appeal from arbitrary decisions of commanding officers should be provided for; and last, but not least, the firemen should not be required to do any more work than is absolutely necessary outside the engineer's department. They are, on the more modern ships, the hardest-worked men in the ship's company, being employed from early morning until late in the afternoon overhauling and repairing machinery; and after this work is done they are exercised on deck in evolutions in which they could not possibly participate in action, as they would then be all required at their legitimate work below.

Then, again, besides getting trained men, we must have more men. The Colossus, which the author quotes, worked 35 "stokers" in the "stokehold" when she made her 7488 I. H.-P., or one fireman for every 214 I. H.-P. At this rate the Atlanta should be allowed 17 firemen on each watch in the fire rooms, supposing that she had as good coal as the Colossus; but with Cumberland coal the extra amount of work would necessitate the employment of 20 per cent more men.

Men accustomed to working fires only under natural draught are at first almost useless on forced draught fires, and not only require training, but they must be kept in condition by constant practice. The severity of the labor on forced draught fires increases much more rapidly than in the same ratio as the I. H.-P. It is only too probable that ships after running their full-power trials will never again use forced draught except in case of emergency, and then the firemen will be found wanting, for lack of practice. Forced draught should be used, on a portion of the boilers at least, for a part of every run, and every ship should have a twenty-four hours' full-speed run at least once a year, to bring the men up to as near the proper standard as possible.

But I must ask to be allowed to digress from the main subject to take exception to the author's comparison of our I. H.-P. per square foot of grate with that of various English ships. In the first place, it is idle to suppose that with Cumberland coal we can get as good results as those obtained from Nixon navigation coal. In Mr. F. C. Marshall's recent article on high-speed marine engines, he gives the results of trials of both Nixon and Cowpen coals in the

same boiler. The Nixon coal evaporated 8.57 pounds of water from and at 212° F., while the Cowpen coal (corresponding to our Cumberland) evaporated but 6.97 pounds. Besides this, our coal contains considerable ash, while the Nixon coal is so clean that the English ships run their full-power trials without hoisting ashes. The author's reference to the expected I. H.-P. of the Nile is unfair in another respect, as she has triple-expansion engines, while the Atlanta's engines work with double expansion, and so the increased performance per square foot of grate is in part due to the more recent design of the engines, and not to better firing.

And here, too, I must protest against the now too common practice of comparing the official results of our trials with the newspaper reports of the trials of foreign ships. For a long time I put implicit confidence in reports of trials which appeared in leading engineering papers, but I have found so many of them false that I have come to such a state of incredulity that I am loth to believe any reports whatever unless the strongest proof of their correctness is furnished.

Experience has taught me that men ordinarily of the highest integrity regard the horse-power of their engines as a perfectly legitimate subject for exaggeration, and would no more hesitate to romance on this subject than would an angler on the weight of his catch, or a mountaineer on the length and girth of various snakes which form the themes of stories which he loves to narrate to open-mouthed and credulous listeners. This practice is of no sudden growth, but has gradually developed. One man shows his engine to make a certain economical performance, and his neighbor, to keep up his reputation, must needs beat his record; and so it goes on until those builders who would like to give truthful accounts of their trials are afraid to do so because they would appear to be behind the rest of the world. All sorts of tricks are resorted to, but the principal ones are the use of overrated indicator springs, and increasing the speed at the moment that the indicator diagrams are taken. Let me cite an example: Within the past year there was received at the Navy Department a set of indicator diagrams from the triple-expansion engines of one of the finest steamers in the Transatlantic service. Here, thought I, was some data about triple expansion that was worth having. The engines were designed by one of the most eminent of English engineers; the ship and machinery were built by a famous firm on the Clyde; and the ship is owned and run by one of the best companies whose vessels ply the Atlantic. There was no need for deception here: the reputation of all parties concerned was too firmly established to need any such assistance; but need I say that my faith in human integrity went down to the lowest ebb when the first application of the given indicator scale showed *seven pounds more initial pressure in the high-pressure cylinder than the pressure in the boiler?* Probably they had counted on nobody being inquisitive enough to examine into such unimportant details. These engines were said to develop a horse-power on 1.32 pounds of coal per hour, but the power actually shown by the diagrams (without any correction of the scale) proved that these figures were entirely too low, as the consumption of coal per day was known from the ship's log. Going a little further, I compared the revolutions at the time the

diagrams were taken with the ship's run for the day, and found that the cards were a set of "show cards" taken with the engines running at considerably more than their average speed. This brought the cost of the I. H.-P. still higher. But I was not content to stop here: the indicator must be made to bear still more testimony against itself. Now, no matter to what unknown extent an indicator scale may be falsified, and no matter whether or not we know the correct number of revolutions, there is an unfailing test that may be applied. As the specific weight of steam varies almost directly as the steam pressure, the ratio between the weight of steam shown by any given indicator diagram and the work shown by the same diagram will be very nearly constant, no matter what may be the scale of the indicator. Applying this test to the diagrams in question, I found that they showed 14.76 *pounds of steam per I. H.-P. per hour*, no allowance being made for losses. It would take a phenomenal boiler, excellent coal, and better water than we have on this side of the Atlantic, to make this amount of steam without the expenditure of a great deal more coal than the quantity claimed.

Another case very similar to this was the trial of the quadruple-expansion engines of the Rionnag-na-Mara, where the cost of an I. H.-P. was said to be 1.125 pounds of coal per hour (vide *Engineering*, April 9, 1886). An English engineer had the temerity to question the accuracy of the trial, and showed that the indicator diagrams accounted for about 14 pounds of steam per I. H.-P. This brought down upon him the wrath of several other engineers, one of whom made himself ludicrous by accusing the critic of unfairness in taking his measure of the steam where the diagrams showed a maximum quantity, instead of from the point where the least steam was indicated.

Going back several years, I may cite the trials of U. S. S. Vandalia and H. M. S. Garnet, which are tabulated by Brassey in Vol. I. of "The British Navy." The Vandalia, at 2033 tons displacement, burning anthracite coal, made 12 knots per hour on 1200 I. H.-P. The Garnet, at 2120 tons, burning bituminous coal, made 13 knots on 2000 I. H.-P. Both ships had the same area of grate surface. By Froude's law of comparison, the corresponding speed and power of a vessel on the Vandalia's lines, but with the displacement of the Garnet, would be 12.08 knots on 1263 I. H.-P. The I. H.-P. for this ship at 13 knots would then be, by a simple calculation, only 1575, instead of the 2000 said to have been made by the Garnet. The two ships are fairly comparable by this method, as their coefficients of fineness are practically the same. But if the published reports of the Garnet's trial are correct, she must have somehow wasted $2000 - 1575 = 425$ I. H.-P. I am inclined to think, however, that no such careless engineering was done by her designers and builders, and that the horse-power was exaggerated in the reports made public.

There are many still earlier indications of this tendency to give incorrect reports of engine trials. It is now nearly a quarter of a century since Dupuy de Lôme publicly remarked that it required more power to drive English ships than French ships of similar size at similar speeds, and attributed this to the finer lines of the latter ships. This aroused the ire of the English shipbuilders; they scoffed at the idea of Frenchmen producing finer models than theirs,

and in order to prove their position they were compelled to virtually acknowledge that the increased horse-power was due, not to the greater resistance of the hulls, but to the less resistance of the indicator springs.

We often hear of trials of very short duration, but they seem to be considered by many people to be of the same practical value as longer trials of other ships, and are quoted on terms of equality with them. For instance, the performance of the Naniwa Kan is frequently compared with that of some of our ships. She is reported as having made 7650 I. H.-P., or at the rate of 19½ I. H.-P. per square foot of grate. Her trial took place over a course of 9.6 knots, one run being made in each direction. The first run, with the tide, was made very nicely indeed, but the run against the tide was not so successful. Before two-thirds of the course had been passed over the steam had run down from 90 to 72 pounds, and the revolutions from 123 to 117; and here the reports of the trial abruptly end. And now it turns out that during these short runs *no water was fed into the boilers*, the trials beginning with water at the tops of the gauge glasses, and ending with no water in sight. The unfairness of comparing such a trial as this with a carefully conducted six-hours' trial must be patent to all.

These are but a few instances which I might mention where the public has been deceived by false reports of trials. The great trouble about the accounts of most trials is that sufficient data is not given and the results cannot be analyzed.

I must apologize for having made this long digression from the subject of the paper under discussion; but I have seen so many proofs of gross exaggeration in published reports of foreign engine trials that, the author having referred to some of these trials, I could not resist the temptation to show the character of some of these reports.*

Passed Assistant Engineer BAIRD.—*Mr. Chairman and Gentlemen:*—I am much gratified to see the subject of training the engineer force brought before the Institute, particularly at this time, when new and powerful steamships are being added to the Navy. The problem of training this force is not new; those

*Since the above was put into print, the Alliance, using ordinary steaming coal as it came from the bunkers, has made a maximum performance of 12.4 I. H. P. per square foot of grate, and a mean of 11.1 I. H. P. per square foot of grate *for a ten hours' run* on regular service, with apparent ability to keep up the same performance indefinitely. This, however, cannot be fairly compared, on a grate-area basis, with the performances of the English ships, as the Alliance's boilers were designed and built for natural draught only; the forced draught having been introduced at the last moment in order to test a new system of applying the blast. And not only were her boilers not properly proportioned for forced draught, but she was using steam of only 78 pounds pressure in engines designed fourteen years ago and in almost constant use for the past twelve years, while all the foreign ships which are reported to have made such superior performances use much higher pressures in engines of the very latest design.

In order to show that I am not alone in condemning the reputed performances of foreign ships, and in deprecating comparisons between them and our own vessels, let me quote from a late number of one of the leading English service journals (*Admiralty and Horse Guards Gazette*, April 16, 1887, page 242): "We are strongly opposed to the present system in regard to the steam trials of Her Majesty's ships. *As criterions of speed they are perfectly useless and utterly delusive.*"

A. D. M.

of us who came into the Navy in the days of side-wheel steamers with jet condensers, and have served through the changes that have passed, have witnessed and have taken part in various organizations, methods, and experiments in the matter of turning our force to the best advantage. There was a time when our force was a good one.

Before touching upon the points so well expressed by the essayist, I beg leave to recall, as a matter of history, some of the forms of organization through which we have passed, that we may be the better able to arrive at a choice, by preventing a repetition of what has worked badly. When I entered the Navy of the United States, during the War of the Rebellion, there was a large number of engineers in the Navy, particularly in the lowest grade of the corps; there was also a large number of merchant-service firemen enlisted in the service. On board large ships the fire room was in charge of a junior engineer, who also 'tended water; the rule was at that time to run the ships at full speed, and to force them frequently; the engineer force was accustomed to urging the fires, and the men either became skillful firemen or broke down completely in a short time. Discipline was at that time good; a commendable emulation existed between the watches as to which should excel in revolutions, and it was at that time conceded that the best result depended more on the engineer in the fire room than on his senior in the engine room. He was the fellow who handled the men; he was the fellow who was looked to "to get the steam." With this in view, and a hope of promotion (which was rapid at that time), the young engineers were stimulated with a desire to inform themselves as to the best method of managing fires and *managing men*. They quickly learned to utilize the men to best advantage, and the men readily learned to work to each other's hand.

The firemen were rarely called upon to perform any duty on deck, and seldom complained of overwork in the fire room, so long as the division of labor was equable. The engineer force was divided in a way to do "the greatest good to the greatest number." When all hands were called to quarters, the watch in the fire room remained there, the first relief went to the steam-pumps and hose, and the second relief to the powder division. The advantages of this distribution are evident. The force was at that time considered as belonging exclusively to the engineer's department, except at quarters, when a part of his men served in the powder division. A boat's crew or a landing party of firemen was always under an engineer; there was no mixing of the men from the several departments of the ship; the engineer's department was then managed very much as on board a merchant steamship.

At the end of the War of the Rebellion the Navy Department began to economize by reducing the number of men in the ships, by placing restrictions on the use of coal and enforcing greater use of the sails. A regulation still exists which forbids the commanding officer from sanctioning more than two-thirds the steam power being used except in cases of emergency, on which occasions he is required to make a special report to the Navy Department. Nor is the two-thirds power defined; it is not known whether the Navy Department meant two-thirds of the power of the boilers when new, or two-

thirds of the power of the boilers as then existing. It is interpreted in more than one way, and on the construction put upon this regulation sometimes depends the reputation of a vessel for speed. I made a cruise on board a gunboat just after the close of the war, when this regulation was new. The vessel was provided with blowers for forcing the fires, which would increase the rate of combustion more than 50 per cent. With these blowers in operation a power of almost 1500 indicated horses had been reached, and a speed of 13½ knots had been exceeded. The vessel had been in use two years, and the boiler pressure had been reduced somewhat; the question arose as to what was full power and what was two-thirds power; the decision—on board the ship—was "all we can get with eight-tenths of the furnaces with natural draught," which resulted in the development of about 800 indicated horse power and a speed, in smooth water, of 10 knots per hour. During all my years of sea service since that period I have seen but one United States Navy vessel run at full speed for an hour.

Not only are we prohibited from exceeding two-thirds the power, but admonished to be exceedingly economical in the use of coal; in fact, I have known the limit of coal per hour to be so small that the problem was to prevent the fires going out entirely. To economize still further, the Navy Department, about the year 1870, abolished the firemen and substituted seamen-extra, ordinary seamen-extra, and landsmen-extra, in lieu of first-class firemen, second-class firemen, and coal-heavers, respectively. The purpose was to sail the ships, using steam to enter and leave port and in emergencies. To accomplish this more fully, the sail area of many vessels was increased; barques were changed to ships, and royals were provided to vessels which had hitherto had nothing above topgallant sails; and that the drag of the propellers might retard the vessel's sailing less, two-bladed screws were substituted for four-bladed ones,—and it was believed that the Navy would be greatly benefited. At this time the junior grade of engineers was abolished, reducing the engineer corps about 50 per cent. The ships could not, therefore, have an engineer in the fire room; in fact, it sometimes occurred that no old fireman could be found among the seamen-extra (who were detailed from the deck when we got up steam), and there was sometimes difficulty, if not danger, in the matter of 'tending water. Of course it was an admirable arrangement for wasting fuel, but as the ship sailed most of the time, this loss was not so great as might be expected. The men being shipped as seamen, etc., were no part of the engineer's force; when they worked in his department it was on a temporary detail, and the same men were not always detailed, so that "training" was out of the question.

The Navy Department, in its wisdom, recognized the mal-organization and reinstated the firemen in their original ratings and wages. The rating of machinist was substituted for that of junior grade of engineer: it had many advantages, but more disadvantages. The ratings of boilermaker, blacksmith, and coppersmith have been created, and though found desirable, the two latter have for some reason been discontinued. The short-handedness of the crews still exists to such an extent that "emergencies" requiring the assistance of the firemen and coal-heavers on deck are rather the rule than the exception. But

with the labor-saving machines—steam windlass, steam hoisting engines, steam steerers, steam ash hoists, etc.—now being generally utilized, as well as the diminished sail area which is being introduced into the ships of latest improved design, we are inspired with a hope that we may again have a division in fact, and an opportunity to train it.

I beg, however, to differ with the essayist in regard to his comparison of results reported from British trials and those made by our own people. Our experience with an air-tight fire room commenced with Mr. Dickerson's design of the machinery of the Pensacola in 1861. It was a failure. With the blowers doing their utmost on board the Atlanta, the pressure in the fire room was $1\frac{1}{10}$ inches of water. To obtain a more rapid combustion, and greater power from the same boilers, these machines will require to increase in power in a higher ratio than does the rate of combustion, on account of the increased leakages; and to obtain the powers claimed by our transatlantic cousins, the figures reach doubtful proportions. The practical difficulties of the air-tight fire room, and the advantages which appear in the Bureau's design of the blast in the Newark, will probably lead to the general adoption of the latter, which, if developed, may put those gigantic powers within our reach. By the use of the blower, our regular navy ships developed as high as 7.57 horse power per square foot of grate surface, during the early years of the war. When the boilers of these vessels were worn out they were replaced by boilers of equal size, *but without the blowers*, and of course the vessels were not as fast, nor could their machinery develop as much "horse power per square foot of grate."

So far as the power developed by the foreign ships is concerned, I must say I do not believe the reports are correct, for the reason that, for the same speed of a given-sized vessel, they report a much higher power than do the French or Americans. The French people raised this doubt before we did. Nor is this exaggeration confined to their Navy. In 1872, when I served in the South Pacific, there appeared several large new screw steamships belonging to the P. S. N. Co. These vessels had compound engines, for which an extraordinary economy was claimed. I visited many of these vessels, and, though never permitted to see their log book, I was given great facilities for examination. The speed of these fine ships and the power developed by their engines, as calculated from the indicator diagrams, balanced very well, but the amount of coal said to be consumed made it appear that an indicated horse power was developed for less than a pound and a half of coal per hour. Of course I did not believe it, though I was sometimes placed in a position which made me feel like the twelfth man on the jury who "never saw eleven such unreasonable men in his life." Later on, however, we obtained from the commanding officers of these vessels extracts from the noon reports of the engineers, which showed a consumption of 55 tons of coal instead of 36, which brought the horse power up to $2\frac{1}{8}$ or $2\frac{1}{4}$ pounds of coal per hour. The unit of measure of the economy of these vessels was in tons of freight per pounds of coal; the comparison of the new engines of war vessels to-day is in indicated horse power per pound of weight: the com-

petition is sharp; the reward is great. There is no doubt about the powers having been enormously increased for a given weight of engine, but I believe the reports from the other side of the water to be greatly exaggerated. By a weak spring in the indicator, or by other jockeying, the power may readily be exaggerated. I am informed that the reports of the trials of British war vessels are not signed by any one; if this is the case, who is responsible for their correctness?

There is probably not a single engineer in the Navy who is not convinced of the necessity for trained men in the fire room, particularly for the vessels now building. I am satisfied that if a man has endurance, weight, and "gumption" he may become as good a fireman in three months as in three years. There is an art in firing, as in every trade, and it is by no means the man who labors hardest that gets the most steam. It is, however, nonsense to put a boy or a light man at a heavy fire; such may be utilized in the engineer's department in many ways, but not at the fires. A boy, if possessed of gumption and good habits, may soon be trained to run a steam launch, or to oil, and will soon become a "handy man" in the engine room. The lifetime of a fireman has been variously estimated at from three to nine years (about the same estimate has been put on puddlers, whose work is before a hot fire)—perhaps a mean, or six years, would be a fair estimate of the duration of this craft or trade; it is evident then, if we are going to get good results from our men, we can afford but little time for "training," so must select good, hardy material, and combine the training with useful work. To have an efficient watch of firemen, it is essential to have a man over them who knows how to regulate them, and who can enforce his orders. The men should not be permitted to shift watches, but the same men should be kept together, that they may know each other's ways and work to each other's hand. The firing of furnaces in sequence is essential to economy and to high results. The order of cleaning the fires has an importance which must not be overlooked. The watch in the fire room should know what fires are to be cleaned by the succeeding watch; there should be an hour for cleaning each fire. These are about all the general points that can be given. The engineer and the water tender are dealing with problems of nature; the elements are constantly varying, and they must shift their constituents, sacrificing one if they would produce another.

It would be much better, on board our war vessels, if the chief engineers had more control of their divisions, and had the same authority over their enlistment as on board merchant ships. As at present practised, the enlistments and discharges of firemen are made by another officer, and on the discharge a fireman's "proficiency in rating" is estimated by a line officer who necessarily has not the means of personally knowing the merits of that qualification. The small discharges of firemen bear the signatures of several officers, but never that of the chief engineer. On board a merchant steamship the chief engineer has all to say about the liberty of his firemen; on board the ships of the Navy it is not so. It is the custom, by the courtesy of the executive officer, to consider the liberty of the firemen recommended by the chief engineer, but the

latter has no recognized right in the matter, and it sometimes happens his wishes are entirely overlooked. Firemen and seamen are punished alike for similar infractions of the regulations or law, but under the present organization extenuations have not always the same effect; for example, a fireman and a seaman may overstay their leave alike, and be quarantined for the same period; the excellence of the former, in his duties below the decks, is hidden from the eyes of the executive officer, while the excellence of the latter is every day apparent; the latter is sometimes rewarded by a release when the former is not. This has always been a source of complaint of the firemen.

The higher wages and the advantages of reaching home often are probably the two principal reasons for firemen preferring the merchant service, though the greatest complaint of these men is about doing drills and work on deck. An old man-of-war fireman rather likes it; he takes advantage of the chance to "wash up," at which process he consumes abundance of time; when the drills are over he takes considerable time "shifting" into his working clothes, and by the time he returns to the fire room he hears "mess gear" piped and rushes on deck to devour his rations; in this way the drills interfere seriously with the efficiency of the engineer force.

I believe the Navy would be more efficient, the ships faster and their machinery in better order, if the firemen were confined exclusively to the engineer's department, even if the fascinating drill of topgallant and royal yards were sacrificed to that end.

Chief Engineer R. B. HINE.—*Mr. Chairman and Gentlemen:*—Mr. Parks' paper calls attention to a crying need of the Navy—a need never felt so much as now, and one which in the near future will become still more imperious. Our new ships are to be steamers. All will depend chiefly, and some entirely, on steam as the motive power. To be efficient, these vessels must have efficient engineer departments. It must not be forgotten that any renown gained by our naval commanders will be based on their having efficient ships and crews as well as officers.

It will be well to have the men and artificers of the engineer's force trained for a time on board steam training or school ships; but I think Mr. Parks overestimates the amount of skill needed by about two-thirds of the force. The duties of second-class firemen and coal-heavers are easily learned. What is wanted from these men is a very moderate amount of skill, combined with great endurance and perfect discipline. And it is here that we are most lamentably deficient. Among engineer officers I have heard but one opinion, and that is, that the discipline in our engine rooms has been steadily deteriorating since about the year 1869, when the ratings of firemen were abolished, and "seamen-extra" created in their places. Although the ratings have been restored, and the pay increased, the discipline has continued to become worse and worse, and this I attribute to the fact that the control of the men of the engineer's force has been more and more withdrawn from the chief engineer—the officer who is held responsible for the department in which they serve, and under whose direction they are supposed to work. Now, it is no uncommon

thing for machinists or firemen to be given leave to go on shore without the knowledge of the chief engineer, and without reference to the work in the engine or fire rooms on which they may be engaged. And it frequently happens, almost daily in fact, and sometimes more than once a day, that the whole engineer's force is called off from its work and sent on deck to help to spread awnings, furl sail or the like, the fire room being cleared by the master-at-arms. This is ruinous to the discipline of the engine room. The men, seeing that their duties below are thus made of secondary consideration to sail drill or other evolutions of that kind, come to regard them as secondary, and cease to take that interest in them which they otherwise would do. Seeing, too, that their liberty on shore, monthly money, and other indulgences depend in no way on the manner in which they satisfy the chief engineer by their skill and zeal in the performance of their duties, they have come, as a rule, to have little regard for the approval of that officer, and they will carry out his orders in such way as may be easiest and most convenient to themselves.

Every ship's company should be moved and actuated by one will—that of the commander. The commander's command is general, and he handles his ship and crew through his executive and divisional officers. In battle, or at quarters, and at all other times, the officer who is in charge of any subdivision of the ship's company, and who is responsible for their performance of duty, should be to those men as a commander, and his orders should be obeyed by them with as much alacrity as if they were issued by the commander in person. This is especially desirable in the case of the engine-room force, as in battle their duties are performed under the eyes of the engineer officers alone, and they will lack the stimulating effect of the observation of the commander.

Only those who have spent some time in a modern fire room where a forced blast is used can appreciate the strain on the physical and nerve powers of those there employed. The heat, even in a temperate climate, is apt to be excessive, and the working and cleaning of the fires will task the strength of strong men to the utmost. And I have seen men of a good deal of experience as water-tenders unnerved by the violent fluctuations of the water level in boilers where the combustion and evaporation were being pushed to the highest limit. Under circumstances like these, the highest degree of discipline is imperatively demanded as the only price of efficiency.

To improve and establish the discipline of our engine rooms, I suggest the following changes :

1st. Liberty on shore and other indulgences to be asked and granted only through the chief engineer.

2d. The men of the engineer's force who may be employed in the engine or fire rooms not to be called thence during working hours, for any routine drills or evolutions except general or fire quarters.

3d. Instead of having the firemen drilled at small-arms, etc., on specified days of the week, have them drilled so many times a quarter, the chief engineer to arrange the times so as to interfere as little as possible with the work under his charge. Under this arrangement, the men would get more drills than they do now, as under the usual system drills are often omitted on account of pressing work in the engine room or unfavorable weather.

These changes, carried out in their spirit as well as to the letter, combined with the instruction before alluded to, will enable us to get the best possible performance out of our ships.

One thing more as to machinists. We could get and retain the best class of men if we provided for each alternate enlistment being spent on shore, the men being employed at navy yards at the current rates of wages. Men of stability and character, such as we need in these positions, are often married, and are unwilling to spend all of their time away from home. They would make the best men to employ on board ships fitting for sea, and those whose shore enlistment had expired could, on re-enlistment, be drafted to the ships on which they had been employed.

Chief Engineer BROOKS.—*Mr. Chairman and Gentlemen:*—I had promised myself the pleasure of listening to the reading of the interesting paper of P. A. Engineer Parks, but at this late day I find I cannot be present; not that I wish to discuss this paper, but to coincide with him in his views, and urge that something must be done in the way of training the engineer force in the Navy if we are expected to make the trials of our ships of war successful, and, as cruisers, make them economical and useful.

The fire-room force of ante-bellum days is not the material for these latter day improvements; we are at least abreast of the times, and face to face with the increasing demand for greater speed for our big ships, as well as for our smaller ones, and with the least possible consumption of fuel. In order to meet this demand, the engineer force on board ships must be possessed of a higher degree of intelligence than that usually found among the firemen, and they must be trained for their duty, which is new and varied.

This training can be commenced on one of the training ships, and after two or three months the men will be ready to send to a cruising vessel to complete the work. On board ship they should be shown the same consideration as other enlisted men.

I have known all hands to be called after morning quarters (this call includes the engineer force) and worked on deck until seven bells; then after dinner the deck hands were allowed to lie around and amuse themselves as they wished, but the engineer force would be required for work in the engine department until supper time, then to respond to another call of "all hands send down topgallant yards."

The apprentice system is a good one; but boys under 17 years should not be enlisted. At the expiration of the term of service the chief engineer of the ship should be the proper person to decide whether or not the man or boy in the fire-room force is entitled to a continuous service certificate and good conduct badge.

Teach and encourage the apprentice with the certainty of promotion to the grade of machinist as a reward of merit. Improve the status of the machinist, give him better quarters on board ship, separate him from the enlisted men, and I am satisfied that we will in a very short time have a much more efficient and trustworthy set of men on board ship.

JARVIS B. EDSON, M. E., of New York.—*Mr. Chairman and Gentlemen:*—Professor Tyndall has somewhere told us that we need but walk through the shops of Woolwich, or any of the great factories where steam is employed, to become impressed with the magnitude and extent to which heat, manifested in the form of steam, becomes a helpmate to mankind. But I think if he had, for his illustration, suggested a sojourn in a modern vessel of war, with its mighty engines for propulsion and its innumerable smaller ones for almost every conceivable purpose, and had seen its mighty furnaces giving life, activity and success to the whole, he would certainly have commended it as a somewhat fitting exemplification of his "Heat as a Mode of Motion." Do not fear that he would have contemplated the machinery to the neglect of the coal pile, with its theoretical, dynamical efficiency, or to the neglect of the all-important question as to how the proper combustion of this legacy of the carboniferous epoch was effected. To him each unit of coal would have represented a certain amount of stored-up energy, theoretically valuable according to its composition, and practically valuable according to the distance it had travelled from the mine added thereto. To such a mind frugality is but the natural outgrowth of a knowledge of the article and of its possibilities, and to misuse or to waste that upon which much may depend, would be to him as though a man bound for the Arctic regions were to be wasteful of his provisions from the outstart, forgetting the important fact that their value increased rapidly according to the distance carried and quantity remaining.

Were such intelligence to be found in the material from which firemen are made, even then skill born of experience would be required to constitute a competent fireman.

Certainly no defense can be found for the almost indifferent manner in which coal is left for ignorance to convert into useful effect. Such a thing as the proper combustion of the coal, and its conversion into the utmost heat possible, and how to reach the best results, receives but the most meager attention from the engineers of the present, and none whatever from the men whose ignorance prevents their even caring. Frugality, if ever approached, ends whenever it becomes necessary to limit the consumption of pounds per diem; while the pounds per horse power developed per diem are hardly considered, if at all. Employes of almost any other class might be either ignorant or neglectful without necessarily causing serious accident to follow; but when such a one becomes the custodian of such a magazine of energy as a steam boiler, active intelligence is demanded both for safety and economy, and no man should ever be allowed in any important position in connection with the operating of boilers unless fairly well conversant with the subject. Because a man is a fireman, does it signify that he shall be nothing but muscular development and incapable of instruction? That men should be thoroughly fitted for and trained as firemen seems as self-evident, so far as the matter goes, as the necessity that men should be trained for engineers before being allowed to act as such. How they are to be best fitted for such duty may admit of many solutions, but certainly is it true that it will repay the Government well in the fuel saved alone, for any expense likely to attend the proper instruction of its

firemen. Ten to twenty per cent of fuel saved daily may represent many dollars during a year's steaming, and men effecting such economy may well receive a rating and compensation somewhat in accordance therewith. It would seem that the proper place for the instruction in such duties would be on board of vessels while not otherwise engaged, and steaming for the express purpose of affording practice and instruction to a set of men, who may be the operatives, and in the presence of others who may be receiving instruction, as witnesses. With a constant load on the boilers, in the way of certain revolutions per minute, competitive runs of four hours each would go far toward determining the skill with which an experienced man would compare in the consumption of fuel for such period with those under instruction. In some such way would men soon learn to appreciate the subject of proper combustion, measured in terms quite comprehensible to them, such as the distance made and the revolutions of the engine effected.

While this special instruction is to be commended, it does not, in my opinion, necessarily follow that efforts should not be made in the same direction on board of every naval vessel, while under steam, on the part of the engineer force accompanying the same; because, while perhaps not so rapidly, but quite as effectually, can men become qualified in the regular practice of the service. Professional pride on the part of the engineer of the watch should certainly demand that he pay the attention necessary to the end that the coal with which he is provided should be properly used—used as though it were paid for by himself—so as to get the utmost efficiency from it. In the ordinary practice on land no such favorable opportunity can be obtained for the practice of frugality under intelligent management, but in the Government service great opportunity exists for the proper edification of the men in the fire room as to the proper methods of firing with the various kinds of fuel provided them. I consider the object of the paper of the evening of great value, as the subject is too commonly overlooked just where much better results should be looked for; and if provision is made for teaching men how to fire, they will be encouraged therein, well knowing that, after their enlistment expires, they will stand a better chance of finding employment on shore at more than laborer's wages.

[COPYRIGHTED.]

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MAY 11, 1887.

COMMANDER C. L. HUNTINGTON, U. S. N., in the Chair.

IRON AND STEEL, AND THE MITIS PROCESS.

BY W. F. DURFEE, M. E.

Mr. Chairman and Gentlemen:—I am announced to speak to you this evening upon "Iron and Steel, and the Mitis Process"—a subject manifestly too vast to be discussed comprehensively in a single lecture.

I shall, therefore, confine my remarks, relative to iron and steel, to certain observations and conclusions made during a somewhat intimate practical acquaintance with these metals for the past thirty years, which I regard as contributing to a correct understanding of their structure, and to their proper treatment in the course of manufacture. I shall then, in conclusion, offer a description of a recent and most promising improvement in the metallurgy of iron and steel called the "Mitis Process."

Allow me first to endeavor to answer the question, "What is wrought iron?" One of the greatest obstacles to a correct apprehension of this question is this:—the way in which a mass of wrought iron is built up is not generally well understood, and the difference of its structure from that of a homogeneous material is not fully comprehended. The term wrought iron is popularly supposed to designate a metal; but it is really the name of a mechanical admixture, which, at its best, consists of clusters of crystals (which may with propriety be regarded as compound crystals) of pure iron separated from each other, as the result of the manipulative processes employed, by films or threads of an unavoidable impurity called "cinder." In the manufacture of wrought iron, the "pig," or other variety of cast iron, is first deprived, in a more or less imperfect

degree, of carbon and other impurities, by what is known as the "puddling process." This process may be briefly described as consisting of four distinct operations; viz.—

1st. The melting of the "pig iron."

2d. The "boiling" of the melted metal in a bath of liquid "cinder" (composed mainly of silicate of protoxide of iron), until the iron (which, owing to its loss of carbon and other impurities, can no longer remain fluid at the temperature employed,) begins to solidify in the form of small granules or crystals, which can be seen moving amid the boiling "cinder" like white-hot peas in a red-hot soup. When the iron begins thus to granulate or crystallize, it is said to be "coming to nature."

3d. The collection by the puddler of these granules or crystals into distinct masses called "balls." These contain much "cinder."

4th. The "squeezing" or "hammering" of these "balls," while still at a welding heat, into more solid masses, which are called "blooms." These contain much less "cinder" and other impurities than the "balls," but are far from being uniform in structure.

The "balls" above named may with propriety be regarded as white-hot sponges of iron saturated with liquid "cinder," which fills all their accidental and irregular cavities.

When the "balls" are "squeezed" or "hammered" (this last operation is often termed "shingling"), for the purpose of expelling this "cinder" and welding the granules or crystals of iron into a homogeneous mass, the attempt is never wholly successful; for the "cinder," as the metal cools, quickly assumes a pasty consistency and flows with difficulty, and all that portion of it inclosed in the interior cavities of the "ball" is simply flattened out or elongated. Hence it will be seen that the "bloom" is composed of a compacted mass of granules or crystals of iron, separated from each other by films or strings of "cinder" of very irregular dimensions.

When speaking of crystals of iron, I mean minute ultimate units of that metal, bounded by well-defined planes, whose intersections always form salient angles. A number of such crystals may cohere and form an aggregation, having bounding planes similar in outline and relative arrangement to those of any single crystal. Such aggregations, or compound crystals, vary in size, and are often regarded as single crystals and spoken of as such, just as we speak of crystals of galena or calc-spar, when, as a matter of fact, the ultimate crystal of each of these substances remains undiscovered, and as undiscoverable as the boundaries of space.

These large or compound crystals of wrought iron are, in themselves, practically homogeneous: that is to say, the ultimate crystals of which they are composed are not separated and kept apart by any foreign substance, but are as nearly in actual contact as the law of cohesion, in obedience to which they are formed, will admit.

Now let us see how a "bloom," the crudest form of a mass of wrought iron, differs in structure from the homogeneous compound crystals of which it is chiefly built up. Such a mass of wrought iron is an aggregation of an indefinite number of such compound crystals as have been described, which are separated from each other by films or threads of "cinder" of very variable thickness; but which, notwithstanding, are mutually attracted with a greater or less degree of force, the minimum value of which is the measure of the cohesive strength of the mass.

Now let us follow the "bloom" as it progresses towards the form of a commercial bar of wrought iron, and examine carefully the structural changes which take place during such progress. When a properly heated "bloom," or other similarly constituted mass of wrought iron, is subjected to the action of the "hammer" or "rolls," the contained "cinder" endeavors to escape from its entangling alliance with the crystals of the iron, and in so doing, each particle thereof is driven into some line of least resistance, which is always finally located in a plane at right angles to the direction of the force acting upon the metal. In other words, if the "bloom" is rolled or forged into a rod or bar, the metal will be acted upon in two directions at right angles to each other,* and its compound crystals will be compressed in directions normal to the exterior surfaces of the bar, and at the same time extended in the direction of its length. Thus the ends of adjacent crystals are forced towards each other, and the intervening "cinder" is compelled to move at right angles to the axis of the bar, and to unite with the films or threads of "cinder" which have become established in parallel lines of least resistance along the flanks of the compound crystals, and at right angles to the direction of the force acting upon the bar.

Fig. 1 is intended to illustrate on an exaggerated scale this arrangement of the elongated compound crystals of iron with intervening

* In forging a bar it is the usual practice to turn it about its axis through an angle of 90° between the blows (or series of blows) of the hammer; and in rolling a bar it is commonly turned through the same angle between "passes" through the rolls.

films or threads of "cinder," the light spaces representing the iron crystals and the dark lines the "cinder"—the force of compression being supposed to act upon the bar in the direction of the arrow.

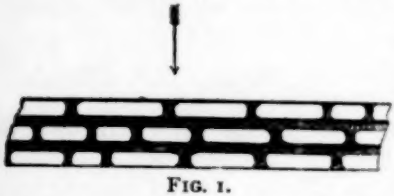


FIG. 1.

Fig. 2 illustrates a method of showing by experiment the character of the structural difference between a bar of wrought iron and one of a homogeneous material such as low steel. In this figure, let *A* be a vertical section of a cylinder provided with an accurately fitted plunger *P*. The space *B* below this plunger we will suppose to be filled with small fragments of lead of irregular dimensions, whose surfaces are covered with a coating of oxide of lead.

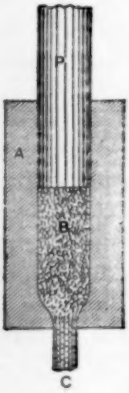


FIG. 2.

If, now, sufficient force is applied to the plunger *P*, the lead will be forced out of the hole in the lower end of the cylinder in the form of a rod *C*, and every fragment of lead will have become more or less elongated, but will be prevented from actual metallic contact with adjacent fragments by a film or thread of oxide of lead. In this experiment, the elongated fragments of lead correspond to the extended compound crystals of iron before named, and the oxide of lead occupies the same relative position in the rod of lead as the "cinder" in a bar of wrought iron. If now, in place of the fragments of lead, we place in the space *B* a solid mass of that metal, then, on applying adequate force to the plunger *P*, there will be forced through the hole in the bottom of the cylinder a rod of lead, whose structural difference from the former rod, made from the oxide-covered fragments, is closely allied to that subsisting between a bar of low steel, and one made of the "cinder"-coated compound crystals of wrought iron.

The direct consequence of the elongation of its compound crystals and the effort of the intervening "cinder" to escape in the direction of least resistance while the wrought-iron "bloom" is being forged or rolled as before described, is the establishment of that structural peculiarity in the resulting bar known as "fibre," which is one of the most conspicuous features of wrought iron, and one not found in any other variety of ferruginous materials.

When any of the films or threads of "cinder" in a bar of wrought

iron are so large as to be distinctly visible on its surface to the unassisted eye, they are called "sand seams" or "cinder cracks."

If its compound crystals are nearly pure iron, the bar can be readily bent cold without fracture, and, if pulled asunder by a gradually augmented force, its fibrous texture is at once evident; but in case the compound crystals have chemically combined with them some substance, such as phosphorus or silicon, which tends to diminish both the cohesive attraction between the ultimate crystals of which they are composed and the mutual attraction of the compound crystals, then the bar cannot be easily bent cold without rupture, and is said to have a "crystalline fracture." Notwithstanding this appearance, however, the mechanical structure of the bar is the same as before; that is to say, the "cinder" and elongated compound crystals are still arranged in lines parallel with the axis of the bar, although it is quite probable that the average length of the compound crystals may be much less than in the case of the bar first described.

Whenever a "bloom" is subjected to a force of compression always acting perpendicularly to the same plane, as is the case when it is rolled into a "sheet" or "plate," its compound crystals and accompanying "cinder" are each flattened and extended parallel with that plane, and the resulting "sheet" or "plate" has more of a laminated than of a fibrous structure, being built up of a number of leaves or strata of iron separated from each other by films of "cinder," which, when unduly thick at any point, cause defects in the plate that are called "blisters."

The foregoing discussion of the structural difference existing between a bar of wrought iron and one of homogeneous iron (often called "low steel") naturally brings to mind an important practical question relative to the employment of wrought iron in construction which is often asked; viz., Will a given sample of wrought iron having a decidedly fibrous texture become crystalline under the operation of a continued repetition of violent strains or shocks? Doubtless many persons of large and varied experience will unhesitatingly answer this question in the affirmative. The sailor who sees his chain cable (known to have been made of carefully selected, thoroughly worked, and honestly tested fibrous iron,) snap short, has no doubt about the metal having become crystalline owing to lapse of time and rough usage. The practical farmer, as he examines a broken trace or plow chain, is firmly of the opinion that the iron

thereof had become crystalline by use. The railway passenger who has fortunately escaped serious injury from an accident caused by a broken axle, is usually ready to testify, with emphasized confidence, that "the iron of the axle was crystalline, and entirely unfit for the purpose for which it was used." A modern fiddle-string bridge goes down under a passing train, plunging a whole community in mourning and sending a thrill of shivering horror through the land—among the various theories advanced to disguise the utter want of sufficient intelligently distributed material in the structure, is sure to be found that of the crystallization of the iron employed.

But let us return to our question. Can a bar of wrought iron of a pronounced fibrous structure be ruptured so as to exhibit a crystalline fracture? I answer, yes,—in two ways. 1st. By a sudden application of a force of extension—commonly called a "jerk." 2d. By a prolonged repetition of a force of compression—sometimes called a "jar."

The first method of rupture may be said to consist of a transverse division of the compound crystals of the bar, as distinguished from a sliding of their interlocking flanks upon each other, as is the case when the rupture presents a fibrous appearance. I have often seen crystalline fractures produced in truly fibrous iron. In the manufacture of iron rails (now nearly an extinct industry), it was always considered desirable that they should be of a hard and crystalline texture as to their tops or "heads," but soft and fibrous in their bottoms or "flanges"; but however perfectly this distribution of metal was made, it was always possible to break a rail so as to show a crystalline fracture in its "flange." This was accomplished by making a slight "nick" across the flange (to determine the point of fracture), and placing the rail ("flange" down) in the "straightening press," on supports placed a short distance on either side of the "nick," and then putting in the "gag" "*heavy*," just over it: the result was almost always a crystalline fracture in the "flange"—in short, the elongated compound crystals were "jerked" asunder. But, if the points supporting the rail were placed further apart, and the rail given an opportunity to yield considerably between them, then, if the "gag" was put in "*light*," a number of times in succession, the fracture of the "flange" would be sure to exhibit a fibrous texture, due to the fact that sufficient time had been given to break up the films of "cinder" along the flanks of the compound crystals and destroy their transverse cohesion, thus permitting them to slide apart, and exhibit the appearance of disrupted fibres.

We are indebted to a not uncommon accident to which the hammer bars of a peculiar type of steam-hammer are liable, for an excellent illustration of the second method of producing a crystalline fracture in fibrous iron, the result of the repeated action of a percussive force of compression. In Fig. 3 is represented at *A* the bar of such a steam hammer. As has been before stated, there exist, in a bar of fibrous iron, films of "cinder" between the ends of its elongated compound crystals (as shown exaggerated in Fig. 1). These, from the nature of their formative process, cannot possibly be of uniform thickness. This, considered in connection with the fact that the greatest force of the percussive action per unit of area of any cross section of the hammer bar is exerted upon a section made by a plane cutting the bar at right angles immediately above its head, justifies the belief that at, or near, this point, fracture would be most likely to occur. It is also evident that the percussive action of the hammer would have more destructive effect upon thick than upon thin films of "cinder"; while, at the same time, the force of cohesion between the ends of adjacent compound crystals will be diminished in some inverse proportion to the thickness of the films of "cinder" between them. It therefore seems exceedingly probable that the fracture due to continued percussion will take place, if not in the plane above named, yet in one very near to it, in which the "cinder" films chance to be of greater thickness than those in that plane; and, as a matter of fact, fractures in such bars are usually within a few inches of the point where the bar enters its head, as at *G*, *H*, Fig. 3.

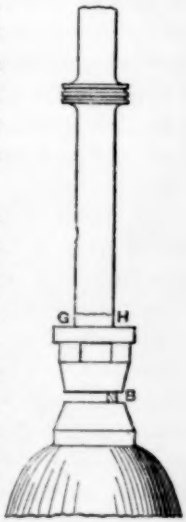


FIG. 3.

The particular point in the circumference of such a hammer bar where the imminent fracture first appears is often determined by the manual peculiarity of the "hammer-man." A left-handed man will incline his work to the left, and a man who is right-handed will be likely to use the right side of the anvil more than the left. In this latter case the work *B*, Fig. 3, will tend (whenever it is in the position shown) to produce a tensile strain at the point *G*, which, as the work is shifted to the centre or occasionally to the left side of the anvil, becomes a compressive strain. We should therefore expect (as is, in fact, the case) that the initial manifestation of the fracture

would be found at that point, and that it would gradually extend towards *H*, until the bar was finally "jarred" asunder. This separation would take place through films of "cinder" between the ends of the elongated compound crystals of the bar, thus exposing those ends, and exhibiting what is called a crystalline fracture.

The belief in this so-called crystallization of wrought iron, as the result of prolonged use, is, I think, altogether a mistake; and I am clearly of the opinion that the crystallization observed in the case of any particular fracture existed just as we see it at the time the metal was given the shape in which it was ruptured. After a bar of distinctly fibrous wrought iron has been subjected to multitudes of sudden "jerks" of extension or "jars" of percussive compression, the "cinder" in some cross section of it (in which this impurity is slightly thicker than elsewhere) gets broken up, cohesion is destroyed, and the bar breaks with a crystalline fracture.

I have had a specimen prepared for the purpose of making the foregoing explanation of the apparent crystallization of fibrous iron more evident. It is a short piece of a square bar of wrought iron. One end is decidedly crystalline in its fracture, showing distinctly that the bar was originally built up of five flat bars. The other end is, for more than one-half of its area, as decidedly fibrous as wrought iron can well be; and this end would have been uniformly fibrous in appearance had the workman who made the specimen exercised the requisite care. Thus, in a sample not over two inches in length, we have an instance of a fracture which most observers would call very bad, and another which as certainly would be called good.

It is a well-known fact that wrought iron is improved in strength by repeated working. This may be accounted for thus:—in the initial heating and shaping of the metal, its crystals were left with a comparatively thick film of "cinder" between them; but, by each successive reworking, the crystals of metal are driven into closer order, some of the intervening "cinder" is expelled, and what remains is very much reduced in thickness, so that the cohesive attraction (whatever that may be) between these crystals, having less space to act through, acts with augmented intensity. It is well to remember, when we speak of "less space" in a matter of this kind, that we are dealing with a very small quantity indeed—one that is a near neighbor to the infinitesimal.

Time passes, and though I could fill the fleeting hour with talk about iron, yet in this lecture, as in the field of mechanical construction, it is now fitting that iron should give place to steel.

What is steel? To the many answers to this frequently asked question, I may perhaps venture to add this one more, namely, that steel is iron freed from mechanically mixed impurities (such as "cinder") by a melting process, during which it has combined with it chemically a small percentage (not large enough to prevent the metal being forged or rolled) of other impurities, introduced for the purpose of modifying its strength, hardness, elasticity, or ductility, in such degree as to adapt it to the particular use to which it is to be applied. In short, while wrought iron is iron having (as the legitimate result of the methods employed in its manufacture) its impurities mechanically mixed, steel is iron having (as the result of the adoption of appropriate manufacturing processes) its impurities chemically combined.

A great deal of the difficulty of correctly fixing the *status* of any given sample of ferruginous material may be eliminated by recognizing the fact, that what is called wrought iron is not really iron, and that the only way in which *pure iron* can be obtained is by electrolysis; a process which is, I need hardly say, commercially impossible for all practical purposes in the present state of our technical knowledge.

I cannot on this occasion describe at length the various processes employed for the manufacture of steel, but will call your attention to certain practical details which are of especial interest and importance.

If we break a large ingot of mild steel (say of 12″ to 15″ square) at right angles to its length, and examine the fracture, we shall find at a distance of from three-quarters of an inch to two inches from its sides, a collection of cavities or "blow holes" (as they are commonly called), which are of an irregular spheroidal form, and of variable size, the largest seldom exceeding one-half an inch in diameter. These holes are separated from each other by partition walls of irregular thickness, and in most instances are coated on their interior surfaces with films of a more or less iridescent oxide of iron. Fig. 4 will serve to give an idea of such a fracture as has been described.

FIG. 4.

There has been a great deal of speculation as to the origin of this array of cavities. Some have supposed that they were caused by gases dissolved in the fluid steel (very much as carbonic acid is

dissolved in water), and that at the moment of solidification these gases separated out, and arranged themselves in the order in which they are found—that of a hollow square (in the case of a square ingot) whose sides are parallel with those of the ingot mould. Others have asserted that oxide of iron is present in the fluid metal, and that this being reduced by the carbon in the steel, carbonic oxide, carbonic acid, or both are set free, which being unable to escape before the steel solidifies, produces the aggregation of cavities we are considering. This theory may be in a measure true in the case of steel containing oxide of iron, but we know that good metal does not contain oxygen, and if the holes were in any great degree due to the reaction mentioned, they would be likely to be evenly distributed through the mass of the ingot, and not confined, as is the fact, to a well-defined zone.

Other suggestions involving more or less occult, hypothetical, and ingenious chemical and molecular considerations have been made; but all fail to account satisfactorily for the symmetrical arrangement of the holes observed.

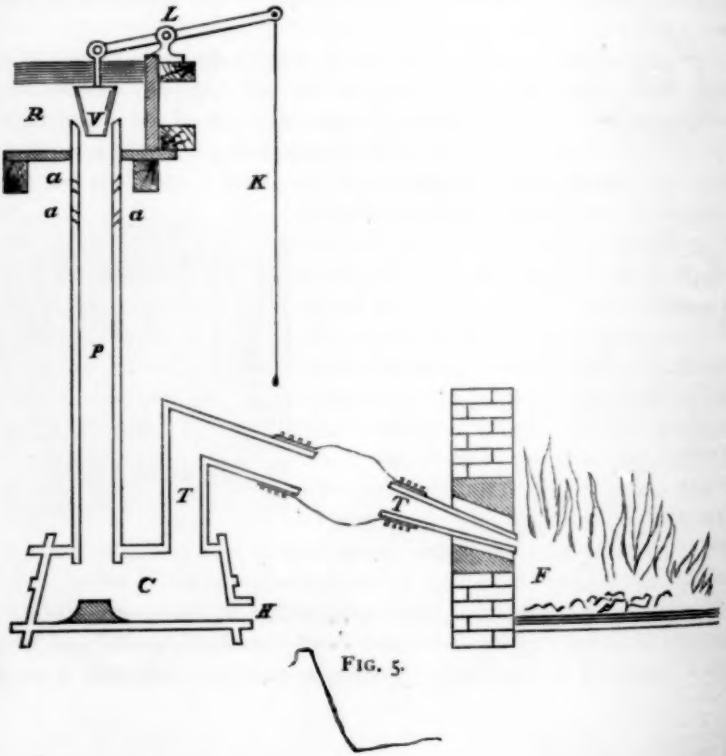


FIG. 5.

My own explanation of the formation and peculiar distribution of these cavities is a purely mechanical one, which I will now endeavor to make clear.

It is a well-known fact that a vertical stream of any liquid descending freely through the atmosphere drags along with it, by frictional contact, a notable quantity of the air or of any other gas that may be in its immediate vicinity. This fact was many years since taken advantage of in the construction of the blowing apparatus called the "tromp," used for furnishing the blast for the forges of Catalonia.

This apparatus consists of a vertical pipe *P* (usually of wood), whose height is determined by that of the head of water at the locality of the forge; the upper end of this pipe passes through the bottom of the wooden race-way *R* (Fig. 5), and is closed or opened by the movable conical plug or valve *V*. Below the bottom of the race-way *R* there are several inclined apertures *a*,*a*,*a*, made in the sides of the pipe *P*. These are for the purpose of admitting air, which, when the valve *V* is raised, is drawn in by the descending column of water, and mixing therewith, is carried downward and discharged thereby into a receiving chamber *C*. Here a separation of the air and water takes place, the former passing through the tuyère pipe *T*, *T* to the forge-fire *F*, and the latter escaping from the receiving chamber through a hole in its side at *H*. The volume and pressure of the blast supplied can be regulated within certain limits by raising or lowering the valve *V*, by means of the cord *K*, acting through the lever *L*.

Over twenty years since (1863), I employed (in the laboratory of the experimental Bessemer steel works at Wyandotte, Michigan) the principle of the mechanism described for supplying blast for a table blow-pipe. The apparatus for this purpose consisted of an ordinary three-necked Woolf bottle *B* (Fig. 6) of about a half-gallon capacity, to the middle neck of which was adapted a cork through which was passed the stem of a small funnel *F*, which reached nearly to the bottom of the bottle. To the right-hand neck of the bottle *B* was fitted the discharge syphon *S*. The left-hand neck of the bottle *B* had fitted to it a bent glass tube *T*, to whose horizontal end was attached a rubber tube for conveying the air to the blow-pipe. To put the apparatus in operation, a stream of water was discharged from a jet-pipe *J* into the top of the stem of the funnel *F*. The diameter of this stream was slightly less than the internal diameter of the tube of the funnel, and could be regulated as regards its volume and

velocity by a suitable cock *C*. As the stream of water from the jet-pipe *J* descends the tube of the funnel *F*, it drags along with it by frictional contact a very considerable volume of air, which, on reaching the bottom of the bottle *B*, separates from the water and passes to the blow-pipe through the rubber tube before named, the water finding an exit through the discharge syphon *S*.

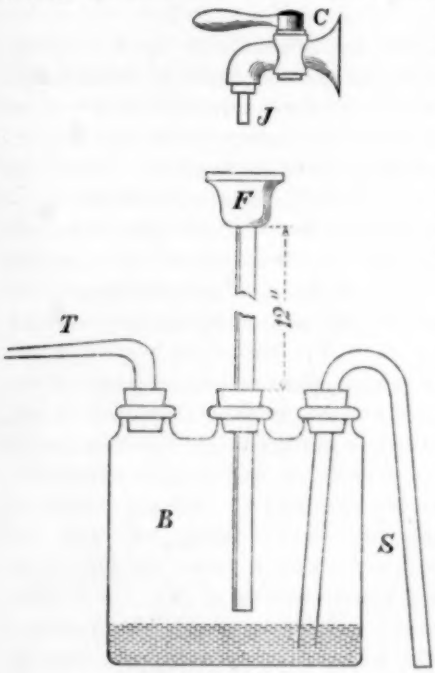


FIG. 6.

Now let us see how the action of the "tromp" and the apparatus just described is concerned in the casting of an ingot of steel.

Let the beaker *B* (Fig. 7) represent an ingot mould, and the descending stream of water *W*, the stream of liquid steel;—it will be seen that the stream *W* carries with it a large volume of air into the water (for illustrative purposes regarded as liquid steel). This air, in its endeavors to escape, turns, and in the form of globules or bubbles takes an upward direction parallel with the sides of the beaker (representing the ingot mould). On the stoppage of the stream, all this air immediately escapes from the water, leaving it as homogeneous as water usually is; but, if during the filling of the beaker the water therein was rapidly frozen (the progress of the congelation being from the sides towards the centre), it is evident that the ascending bubbles of air would be entangled in the ice as it formed, and we should have as a final result a vesicular mass or ingot of ice, quite similar as regards its method of formation to the ordinary ingot of steel.

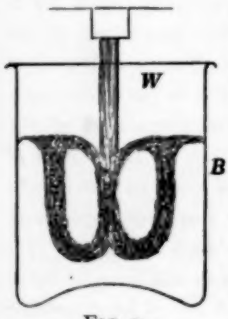


FIG. 7.

Another illustration may make the formation of vesicles in steel

ingots still more clear. If in place of water in the preceding experiment we substitute mucilage, or any other fluid of similar consistency, we approach much nearer to the actual conditions which exist in the casting of a steel ingot; for the steel as ordinarily melted is never as fluid as water, but approximates more nearly in mobility to the character of mucilage. As, then, the stream of mucilage descends, it will be observed that it carries with it air in the same manner as the stream of water; but that owing to the viscosity of the fluid, the air bubbles rise through it more slowly and escape with greater difficulty, and that some of them, as they approach the surface, are again dragged down by the central descending current. Hence there is a much larger collection of bubbles of air in the mucilage than there was in the water, and, consequently, if the mucilage was solidified at the moment the descending stream was stopped, we should have a much more vesicular mass than in the case of the frozen water in the last experiment.

In comparing the foregoing experimental illustrations with the actual conditions which exist during the casting of an ingot of steel, we find an ingot mould of cast iron (corresponding to the beaker), which is filled by a rapidly descending stream of molten steel (corresponding to the water or mucilage), not as liquid as water, but more nearly of the consistency of mucilage. We also find that this stream carries into the imperfectly fluid mass of steel which rapidly fills the ingot mould a large volume of air, which attempts to rise and escape from the rapidly cooling and solidifying mass of metal in precisely the same way as the bubbles of air endeavored to escape from the water and mucilage in our two illustrative experiments.

But we find another condition present in the case of the molten steel that did not exist in either experiment; viz., the fact of a high temperature in the fluid metal. If we examine this condition, we shall readily discover that it has a very important influence both on the size and number of the vesicles included in the ingot of steel; for it is a well-known fact that dry air, for each 480° F. increment of temperature, increases its bulk by the amount of its original volume. Now, as the fluid steel is at least of the temperature of 3300° F., dry air introduced in the manner illustrated would be so expanded as to occupy seven times the space in the ingot that it did in the atmosphere.

There is, however, yet another fact that tends still further to augment both the size and number of the so-called "blow holes"

that we are considering. It is a well-known practical condition that the air in the immediate vicinity of steel-casting pits is far from being dry. The large quantity of water used for cooling ingot moulds, and for other purposes, keeps the atmosphere surrounding both casting-ladle and ingot-mould in a very moist state, and it is certain that all such vapor-laden air carried into the molten steel would increase in volume for a given increment of temperature very much more than dry air, and would therefore correspondingly increase the size and number of the "blow holes." Furthermore, this vapor of water does not act to this end altogether through its expansion under the influence of heat, for some, if not all of it, is decomposed by the high temperature, and its oxygen, together with that of the accompanying air, is absorbed by the walls of the cavities. This produces the iridescence observed, and leaves in the "blow holes" an atmosphere composed mainly of hydrogen and nitrogen; and it is not at all improbable that in many cases this decomposition of the watery vapor did not take place until the steel was so far solidified as to prevent the walls of the cavities yielding to any great extent, and, under such circumstances, the gases named would be under a very considerable tension.

This view is confirmed by the investigations of Prof. F. C. G. Müller of Brandenburg, who found that the mean composition of the gases in the "blow holes" was

Hydrogen, ...	79 per cent.
Nitrogen, ...	19 "
Carbonic oxide, ...	2 "
	100 "

and that their average pressure was 120 pounds per square inch.

It is of course possible that some of the gases found in the "blow holes" of Bessemer steel ingots may have found lodgment in the steel during the process of "conversion," more especially when steam is admitted with the blast for the purpose of keeping down the temperature of a "hot blow." In this case the steam would certainly be decomposed, and some of the residual hydrogen might remain entangled in the metal; although doubtless much the larger portion owing to its great levity, would escape during the pouring of the steel from the "converter" into the "casting ladle." In the case of open-hearth steel, however, there would be no such reason for the presence of hydrogen.

The foregoing explanation of the presence and methodical arrangement of the cavities or "blow holes" in steel ingots, and the character of the gases found in them, is, I think, sufficient to account for all the facts observed. The assertion which has often been made (as a sufficient explanation), that "the gases are occluded in the steel," deserves to rank with the pompous declaration of a village pedagogue that a total eclipse of the sun which was terrifying his neighbors was "only a phenomenon." "Words of learned length and thundering sound" discourage rather than stimulate the inquiring mind.

I now desire to call your attention to a species of cavity much too frequently found in forgings of steel, that does not originate in the manner already described.

If a large cold ingot is put into a too highly heated furnace, its exterior surface will expand so much faster than the parts at or near its axis, as to strain the metal in the interior of the ingot beyond its elastic limit, and oftentimes actually rupture its central continuity, as is shown at *A*, Fig. 8. Such a breach may in some cases have a diameter equal to half that of the ingot.

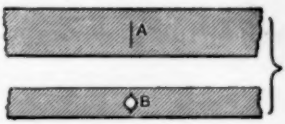


FIG. 8.

An ingot thus internally fractured, if hammered or rolled down to a smaller section, will have a cavity developed in the centre of its mass, as shown at *B*; and unless the existence of this cavity is discovered, serious difficulty may result from the use of such a forging as a part of any mechanism. It is not at all impossible for a number of such cavities to be formed in the same ingot, if the heating be sufficiently rapid, in which case the initial rupture would occur at *A*, Fig. 9, at or near the centre of the ingot; a second and third fracture would

FIG. 9.

then take place almost simultaneously at *B*,*B*, about half way between *A* and the two ends of the ingot; and, finally, a third set of internal breaks may be formed at the points *C*,*C*,*C*,*C*, thus dividing the ingot into eight nearly equal parts of solid metal. The diameters of the several ruptures would vary in the following order, viz: That at *A* would be the largest, those at *B*,*B*, somewhat less, and those at *C*,*C*,*C*,*C*, least of all. Such an ingot—if the internal ruptures were not too large—might be forged into a propeller shaft and actually

put into a vessel, without the defects being discovered until it was twisted asunder on its first voyage.

Such possibilities of carelessness in the manufacture of heavy forgings of steel as I have described make it highly desirable that some method be devised to detect the presence of such internal ruptures before much time and labor have been expended upon the forging, and also to prove its soundness when completed. About twenty years ago, a plan for this purpose was proposed by Mr. S. M. Saxby, R. N., and some extended experiments to test its practical value were made by direction of the Admiralty; but, although the early investigations were very promising, the method has not become established as one of the acknowledged reliable means of testing forgings of iron or steel.*

It is possible that some method of electrical examination may be found of service in testing the soundness of forgings, and I will venture to suggest the following:—

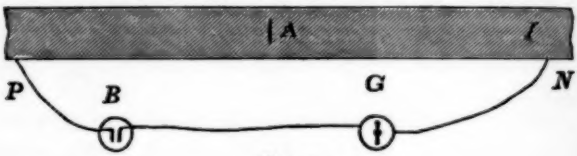


FIG. 10.

Let *A*, Fig. 10, be an internal rupture in the ingot *I*, to the extremities of which are connected the wires *P*, *M*, of the battery *B*, having in the circuit a galvanometer *G*. Under these conditions the galvanometer needle will be deflected a certain amount, which is a function of the strength of the current and the resistance of the circuit; and if by any means the resistance of the circuit is diminished, the deflection of the needle of the galvanometer will be increased. For instance, if, in the proposed apparatus, the wire *N* be moved towards the left, for each inch of movement there will be a corresponding increase of deflection of the needle of the galvanometer; but when the wire passes a point opposite the rupture *A*, the law of the increase of deflection may be found to change, and to indicate the presence of an internal breach of continuity in the ingot or forging under examination. I have had no opportunity to test this method, but make the

* This method is described in an article which was first printed in *The Engineer*, Dec. 7th, 1867, reprinted in *Engineering*, Dec. 13th, 1867, and subsequently embodied in Kohn's Treatise on Iron and Steel, 1869.

suggestion in the hope that some one having the means and leisure will give it a thorough examination, and that it, or some modification of it, may be found of practical value.

Thus far I have spoken only of the transverse internal rupture of steel ingots in consequence of too rapid heating; but longitudinal internal ruptures can be, and often are, produced by the same cause.

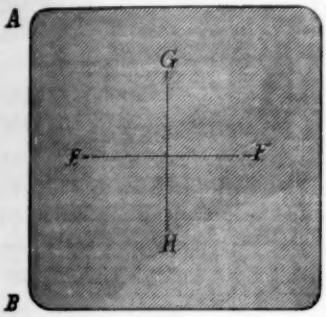


FIG. 11.

In Fig. 11, let *ABCD* represent a cross section of a steel ingot. If too rapidly heated, the opposing sides *AB* and *CD* will expand so much faster than the centre, that an internal rupture *EF* may be formed; and the expansion of the sides *AC* and *BD* may in like manner develop a similar rupture *GH*, located in a plane at or nearly at right angles with that already named.

Such ruptures, though generally situated in planes at or nearly at right angles to each other, are not confined to planes located as shown in Fig. 11, for the planes of rupture may coincide with the diagonal planes of the ingot, or may occupy any position between such diagonal planes and that shown in the figure. In fact, their position is fixed by the resultant action of two forces, due to the expansion of the exterior of the ingot by the sudden heating, modified by the powerful internal strains existing in the cold ingot tending to separate the metal at its centre. These strains were established at the time the metal originally solidified in the ingot mould, and are occasioned by the outside of the ingot cooling, while its interior is either fluid or plastic; and as the whole mass becomes cold, its interior, by the force of cooling contraction, is strained in many cases beyond its limit of elasticity, which limit may with propriety be defined as the beginning of rupture. An ingot of steel thus internally strained would require but the small addition to the tension which a too rapid heating of its outside would furnish, to produce such interior longitudinal fractures as have been described. The extent of the influence of such internal strains in all stages of the manufacture of steel is very irregular and uncertain, and this fact makes them all the more worthy of consideration in all cases in which steel is to be subjected to uses which involve the application of sudden and violent shocks.

Of the effect of such strains in steel used for the construction of cannon, Col. Eardley Maitland, R. A. Assoc. Inst. C. E., Superintendent of the Royal Gun Factory at Woolwich, in a recent paper said: "On a review of the results obtained, the author, having seen so many instances of the fracture of steel, sometimes spontaneous and sometimes under stresses quite inadequate to produce the result, was of the opinion that internal strain was the gun-maker's worst enemy, and that it was a question of great moment whether it was worth while to incur the risk of setting up such strain by oil-hardening."

It is not at all improbable that in many instances (especially in the case of steel having considerable hardness) ingots may be ruptured internally both transversely and longitudinally, thus aggravating the evil of either single species of rupture. If such an ingot were forged into a heavy crank pin, its whole interior would be permeated with most irregular and intricate imperfections, though at the same time the ends and cylindrical surface of the forging might have every appearance of soundness.

As a practical illustration of the great importance of the subject we have been considering, I cannot do better than quote the description of a defective forging given by Professor Thomas Egleston in Transactions American Society of Mechanical Engineers, Vol. VII., p. 263. He says: "I have recently had occasion to examine a forged crank pin made with great care from the best of open-hearth steel. It was rough turned to 16⅝ inches. To ascertain its quality in the centre, an inch and a half hole was bored through it. This hole revealed such a number of cracks and cavities that the hole was increased to four inches, in the hopes of cutting them out. Defects of considerable size were still found. The pin was then sawn in two [planed apart longitudinally], where single horizontal cracks 10 inches in diameter and ⅜ inch wide were found, and inclined ones 7½ inches long, in which were cavities ½ an inch wide, to say nothing of defects of minor importance. None of these defects would have been revealed but for the forethought of examining the centre of the piece. If it had been used without this examination, it would have produced great disaster."

I also have had an opportunity of examining the forging described by Professor Egleston, and was told that it was made by one of the oldest and most experienced manufacturers of such work in this country. My experience teaches me that such defective forgings are far more common than the managers of our steel works and forges are disposed to admit or even believe.

It is a common opinion that one of the reasons why steel forgings are often found hollow in their interior is the failure to work them under a sufficiently heavy hammer; but no hammer, not even "the hammer of Thor," can do more than aggravate the evil of internal ruptures in ingots of steel.

But let us now turn from this long digression relative to internal ruptures in ingots and forgings, and resume the consideration of the matter of "blow holes" in steel ingots. Having endeavored to explain and illustrate what I regard as the principal cause of the formation of such "blow holes," allow me now to examine some of the consequences of their presence.

The first result of hammering or rolling a vesicular ingot will be nearly to close the "blow holes." I say nearly close advisedly; for although the vesicles may become divided, and be made to change their shape and vary their capacity, even to the extent of becoming microscopically small, they never wholly disappear.

As the "blow holes" are reduced in diameter, the contained gases are therefore subjected to a very great reduction of volume, and consequent increase of pressure in the inverse proportion to such reduction. For instance, if the initial pressure of the gases in the "blow holes" was 120 pounds per square inch (as observed by Professor Müller), and these cavities were, by hammer or rolls, reduced to one-tenth of their original diameter, their capacities would be but one-thousandth as great as at first, and therefore the pressure of the contained gases would be $120 \times 1000 = 120{,}000$ pounds per square inch. But, in estimating the value of this pressure to produce rupture, we must bear in mind that it acts only upon an area one one-hundredth as great as it did originally.

Now let us suppose that an article made from steel in the above described condition is subjected to a heat of 1000° F. (a dull red). In that case, the gases inclosed in the cavities of the steel will, by reason of their tendency to expand, exert three times the pressure that they did when cold, and if such pressure is symmetrically distributed (a not very likely circumstance), the article will when cold retain its original contour; but, if there is more internal pressure upon one side of the object when heated than upon its opposite, distortion will naturally result, a thing not at all uncommon in annealing articles of steel. Thus we see that throughout a bar or other forging made from a vesicular ingot of steel there may exist a vast number of magazines of force, of great though very variable intensity,

but quite sufficient to aid powerfully any external strain which tends to break the bar.

Now let us see what would be the result if the "blow holes" were without gaseous contents. Were it possible to find an ingot whose "blow holes" were absolutely empty, when it was worked, the sides of the holes would come together, but, owing to the low temperature, they would not weld. At the same time, the holes would become elongated and be made to approach each other transversely, and, in fact, would finally develop into "seams" of a variable length and depth, as they chanced to originate from large or small holes. Such a state of affairs, as may be readily understood, could have very little influence upon the ultimate ability of the bar to resist a tensile strain; but, if such a bar were subjected to compression, it is easy to see that it would yield unequally, and much sooner on the side having the greater number of such seams.

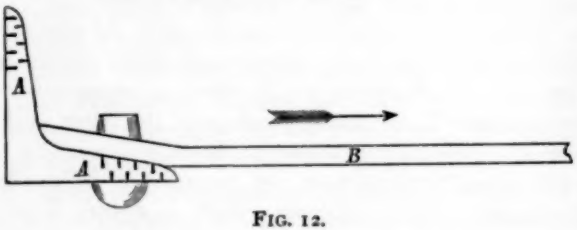


FIG. 12.

But it is when such a bar is subjected to a transverse strain, tending to pull it apart in a direction perpendicular to that in which it has been worked, that these seams are the most injurious. Take, for example, an "angle iron" made from such an ingot: it is not at all improbable that the "seams" would be so arranged in the flanges (as at *A*, *A*, Fig. 12) as nearly to separate them into a series of rods held together transversely by occasional ligatures of metal. Now, if such a bar be punched or drilled through the "seams," and another bar *B* be riveted to it (as shown in the figure) and subjected to a strain in the direction of the arrow, it is self-evident that the "angle bar" would be much more likely to be pulled apart transversely through the rivet-hole than if it were made of a homogeneous material.

I think I have said enough about "blow holes" to convince any one that under the ordinary methods of manufacture they are very likely to occur, and that they are exceedingly objectionable things to

have in the metal; and now let us examine the efficiency of some of the methods that have been devised to mitigate the evil of their presence.

Some years since, the late Sir Joseph Whitworth proposed and practically carried out a mechanical process of compressing steel in the ingot mould while it was still fluid or plastic, his intention being to destroy the "blow holes" by the action of the enormous pressure employed. He certainly succeeded in turning out from his works most admirable products in steel; but I have always had a feeling that the high character of his forgings was due more, much more in fact, to the chemical constitution of the metal, and its having been skillfully heated and carefully worked, than to any qualities resulting from its having been compressed while in a fluid state.

Let us examine this matter a little more closely. Suppose *I*, Fig. 13, to be a vertical section of an ingot mould filled with fluid steel *S*, (having more or less "blow holes" distributed through its mass, as indicated by the small circles,) which may be forcibly acted upon by the plunger *P*. Now, as fluids under pressure act equally in all directions, it is evident that all the "blow holes" will be reduced in size, and also that the tension of their contained gases will be increased in the inverse proportion to their reduction in volume; but it is not so clear that there is any action that will cause their removal from the steel altogether.

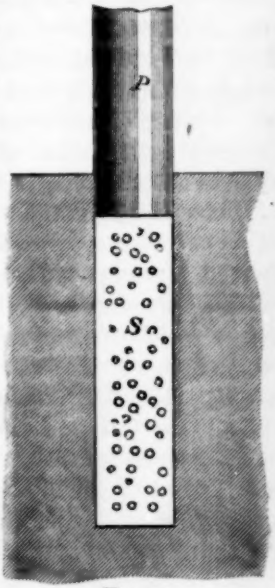


FIG. 13.

The same reasoning applies to all systems of vertical compression, whether by the action of carbonic acid, as employed by Herr Krupp, or by high-pressure steam, as at one time used in this country.

Some system of closing the top of the mould and producing a vacuum above the steel would seem to be a more rational mechanical method of removing the "blow holes," than any system of compression; for, as the pressure upon the steel was reduced, the gases in the "blow holes" would expand, and their augmented levity would cause them to escape from the fluid steel with greater rapidity than is possible under any other condition. But, after all, the simplest

way of getting rid of the "blow holes" in steel is so to treat the metal before it is run into the ingot mould, that its capacity for heat is increased to such a degree that it will remain fluid long enough to permit the gas-filled "blow holes" to escape as freely as bubbles from water.

This suggestion brings me naturally to a consideration of the "Mitis process"; but before entering upon it, I desire to speak briefly of some points relating to the very important practical operation of hardening and tempering steel. As regards the latter process, it would be for the advantage of all who use tools of steel, if the subject could be disposed of in as few words as comprised a somewhat famous account of snakes in Ireland, which simply declared that "there are no snakes in Ireland." I wish it were possible to say that there is no such thing as the present practice of tempering steel; for I am firmly of the opinion that much better results can be attained in its use by simply hardening it at such a temperature as by practice with the particular steel used is found most satisfactory, and omitting altogether the lawless and uncertain operation known among mechanics as "drawing the temper."

I have in my possession an admirable illustration of the possibilities of the methods suggested, in the shape of a razor made from the first Bessemer steel produced in this country. This steel, judged by the ordinary standards for "razor steel," would be considered altogether too soft for the purpose; but, nevertheless, by hardening it as much as possible, and leaving it in that condition, it made so satisfactory a razor that my father shaved himself with it for fifteen years.

I have already referred to the views of Colonel Maitland relative to hardening steel, and feel sure that the practical experience of all who have had the most to do with that operation leads to a similar conclusion.

In this connection it will be instructive to quote some of the remarks made by acknowledged experts during the discussion of a paper communicated to the American Society of Mechanical Engineers by Professor John E. Sweet ("The Unexpected which often Happens"; see Transactions American Society of Mechanical Engineers, Vol. VII., pages 156 to 160). In this discussion, Mr. Henry R. Towne, President Yale & Towne Manf. Co., speaks of numerous unsuccessful attempts to harden certain castings of steel, and states that it was finally discovered "that the steel hardened beautifully *inside*, but that there was on the outside a thin skin of metal,

about three to four hundredths of an inch in thickness, which, except by the cyanide process, did not harden at all. In all of the castings there was perfect hardening under this skin; and finally, the moral of this is that we should *look below the surface*"—a moral, I will add, which should not be forgotten by those who hope to succeed in the employment of steel. In the same discussion, Mr. Geo. M. Bond, Superintendent Gauge Department, Pratt & Whitney Manf. Co., said: "We find in our experience in making taps and reamers, that in case the steel has been over-annealed and has thus been decarbonized, the hardening does not take effect except under the surface, so that frequently, taps which appear to be soft, if turned again will harden perfectly. I think perhaps the castings referred to by Mr. Towne may have been over-annealed, and in that way a percentage of the carbon eliminated so that the hardening would not take effect upon the outside surface." In the same discussion Mr. Bond further remarks: "We had occasion to make a set of gauges in which the sizes were all two ten-thousandths of an inch larger than the nominal sizes, and five days after the gauges were finished, one of them suddenly gave way in the centre, a crack extending around it spirally, but not so as to injure the ends of the gauge. Out of curiosity, I thought that I would measure the uninjured parts to see if any change had come in the diameter, and I found at both ends the diameter had enlarged forty divisions of the micrometer, which is equal to six ten-thousandths of an inch, and which, as magnified, represented a space to the eye of about three-sixteenths of an inch under the microscope. This shows, I think, that if steel hardens at all, the internal strain must be something tremendous. This will also explain why steel, in being hardened through the centre, has a tendency to shorten under certain conditions."

Professor William A. Rogers, Assistant Professor of Astronomy, Harvard University, said: "The unexpected has *always* happened to me in this matter of obtaining hardened steel which has a homogeneous temper throughout the entire mass. The nearest approach to an even temper which I have ever been able to obtain has been at the works of Miller, Metcalf & Co., of Pittsburgh, and of Brown & Sharpe, of Providence. A short time since I asked the latter firm to set a price upon a hollow steel cylinder six inches in diameter, three feet in length, having walls half an inch in thickness, hardened and ground on the outside only. The price which was set—from $300 to $500 without guarantee against flaws—may be taken as the estimate

of the extreme uncertainty always attending any difficult case of tempering held by those who have a full comprehension of the difficulty of the problem.

"The difficulty of giving a homogeneous temper to a large mass of metal is so great, according to my experience, that it is never perfectly done. The test which I apply as the gauge of an even temper is a very severe one. If all the lines ruled upon a highly polished bar of tempered steel have the same appearance, the temper of the graduated surface is good. I have, however, never yet seen a set of graduations in which the diamond has with a constant pressure cut all the lines to the same depth. The diamond acting upon this polished surface detects the lack of homogeneity in the most perfect manner. If there is any person in this country, or in the world for that matter, who can temper a bar of steel three feet in length and for a depth of even a quarter of an inch, at any price, I should be glad to make his acquaintance."

Mr. George Ede, in that chapter of his work on "The Management of Steel" (edition of 1866) descriptive of the method of "toughening of steel in oil," as at that time practised "in the Gun Factories' department of Her Majesty's Royal Arsenal, Woolwich," says, relative to hardening solid steel shot: "Thick lumps of highly carbonized steel, whether hardened in oil or pure water, or water with a film of oil upon its surface, cannot be hardened without becoming fractured either internally or externally." In this matter of hardening steel, the value of the "personal equation" of the workman is all important. It is not uncommon to find a practical mechanic who usually has good success in the use of a certain kind of steel with which his neighbors, equally skillful perhaps in other matters, can do nothing. So often have I encountered this fact, that I am inclined to believe that if a person in pursuit of information as to the proper quality of steel to use for any given article should travel through this land and obtain the honest opinion of all who were making the article in question, that "the last state of that man would be worse than the first"; for the chances are that every person consulted would have an opinion differing from those of his fellow-craftsmen, and although when our traveller started on his search for technical wisdom he was positive that he knew nothing, he could not rejoice in even that negative certainty when he returned. In the present state of our knowledge, there is no recognized uniform scientific method of hardening and tempering steel: all we have is a tentative art, as crude in its development as it is obscure in its origin.

And now let me crave your indulgence for a few words relative to the "Mitis process." The word "mitis" is a Latin adjective, meaning mild, soft, or ductile, and it was selected because of its appropriate signification, as the designation of the new art, by its Swedish inventors.

I regard this process as one of the most important improvements in the metallurgy of iron and steel that has been brought forward during the past twenty years. By its means we can produce castings of melted wrought iron, or of steel of any desired hardness, that, without having been annealed, can be forged, welded, bent cold, or worked by machine tools, with as great facility as ordinary forgings of wrought iron and steel.

From among various samples I have selected two articles which will serve to give a good idea of the possibilities of the new art. One of these is a horse-shoe with "nail holes" and "creases" complete, cast of melted wrought iron in an iron mould—an impossibility by any other process. The other is a beefsteak pounder, in the condition in which it left the "dry composition" mould in which it was cast; this also is made of melted wrought iron. On the extremity of each tooth there is what appears to be a wire. These seeming wires were made by the melted wrought iron filling the "vent holes" of the mould; a thing which I never saw to anything like the extent shown in this sample in the case of castings made of any metal by any other process. In fact, one of the most remarkable attributes of this new art is the extreme fluidity of the metal at the time of casting, and in this fact is one of its greatest technical advantages; for this exceeding fluidity enables all the "blow holes" to escape before the casting or ingot solidifies, thus getting rid of one of the chief obstacles to sound forgings in iron and steel.

This fluidity of the melted metal is produced by the addition of a small percentage (0.05 to 0.1 of one per cent) of the metal aluminium to the melted wrought iron or steel immediately before casting: this addition at once produces a degree of fluidity in the molten metal comparable with that of water.

The reason for this result cannot be explained, but it can perhaps be made more comprehensible by an illustration.

The soft metals—tin, lead, zinc, antimony, bismuth, etc.—melt singly at temperatures varying from 600° to 1000° F., but if a proper selection and combination from these metals be made, we shall obtain an alloy that will melt at the surprisingly low temperature of 170° F.

Under ordinary conditions, melted wrought iron or low steel is pasty or semi-fluid, and it has been found that, without increasing the temperature, the addition of the small percentage of aluminium named acts upon the metal very much as the soft metals in our illustration act upon each other,—it increases the fluidity of the mass, and thus enables results to be attained that have hitherto been impossible. Castings made by this process are, as a rule, ten per cent stronger than the scrap iron melted to produce them ; and in the case of steel there is a like increase of strength without any diminution of elongation previous to rupture, a property which is of great practical value. I regard this process as of great value in the manufacture of material for great guns, as by its use sounder and stronger ingots of steel can be insured from which to forge the component parts of built-up guns; and, furthermore, I believe it quite possible, by the use of this process in connection with the Rodman system of casting, to make a solid cast-steel gun that will be more efficient and a great deal cheaper than any built-up gun can possibly be.

The question of national defense is no trivial one, and before deciding upon the method to be adopted in the manufacture of our future arms, the merits of all systems should be carefully considered. The laudable purpose of our government to provide adequately for the defense of the nation gives to the general subject of the manufacture of heavy guns great interest at this time. That people who would preserve peace must be prepared successfully to defend peace; and a nation so prepared will rarely need to use its weapons.

The industrial victories of peace make possible war's triumphs in the defense of peace. And therefore a nation's first step in its own defense should be to foster the industries of its own people, and cordially encourage those who, with thoughtful brain, willing hand, and ready purse, stand prepared to mine coal and ore, to make furnaces roar and melt with fervent heat, while mighty engines throb and ponderous hammers beat, and, anon, gigantic tools, in whose stalwart frames and cunning fingers are crystallized the brain and brawn of generations of workers in thought and substance, give final shape and proportion to the arms of our defense, that peace and concord, prosperity and happiness, shall be ours while time endures. To this end should all labor tend—

> "Till the war drum throbs no longer, and the battle flags are furled,
> In the Parliament of man, the Federation of the world ;
> When the common sense of most shall keep a fretful realm in awe,
> And the kindly earth shall slumber lapt in universal law."

DISCUSSION.

Lieutenant R. R. INGERSOLL.—*Mr. Chairman and Gentlemen:*—I have only one objection to offer to what the author has said in his able and instructive paper, and that is as to the possibility of making a modern gun with Mitis iron or steel by the aid of the Rodman process of casting. There is but little doubt that a sufficiently strong gun cannot be produced by the Rodman system of casting, for the simple reason that, however beautiful the theory, it is impossible to realize in practice the state of initial compression of the bore indicated by the theory. This is conclusively shown in the case of cast-iron guns, the process of casting which is very much easier than is the case with steel guns. The elastic limit for compression of cast iron being taken at about 26,000 pounds per square inch, the initial compression at the surface of the bore of the completed gun should equal this amount in order to compete with built-up guns; but thus far, an initial compression of 12,000 pounds, in the case of the 12-inch cast-iron gun built at South Boston, is about the limit reached. Again, the elastic strength of Mitis iron being, as compared to gun steel, not over two-thirds the latter, the material is not sufficiently strong, especially in view of the fact that the day is not far off when 2500 f. s. and 25 tons pressure per square inch will be as common as 2000 f. s. and 15 tons pressure per square inch are to-day.

I am glad to hear the author take such strong ground as he does in regard to the existence of blow holes in steel castings. It is as strong an argument as can be desired against the practicability of producing sound, strong guns of cast steel by the Rodman process.

The paper is most interesting and instructive, and I regret that the author is not present, because he could, perhaps, clear up many points upon which some of us may possibly be doubtful.

The following reply to Lt. Ingersoll's remarks was received by letter:

MR. DURFEE.—*Mr. Chairman and Gentlemen:*—In reply to the criticism of Lieutenant Ingersoll, I will say that the behavior of melted wrought iron or steel, when treated by the "Mitis Process," is so different from that of these metals not so treated that, in the absence of actual experiment, it is hardly just to assert that this new process is not available for the manufacture of heavy guns by the Rodman system, or some modification thereof; and if a thorough trial should prove its unfitness for use in this way, it could hardly fail to be of great value in ensuring sound ingots from which to forge the parts of built-up guns.

In view of the many failures of built-up guns made by the aid of the best talent and largest experience abroad, I think it the part of a conservative wisdom to hasten slowly enough in this (for our country) new manufacture; to "prove all things and hold fast that which is good."

On the motion of Commander W. T. Sampson, a vote of thanks was given to the author for his valuable and instructive paper.

[COPYRIGHTED.]

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MAY 6, 1887.

COMMANDER P. F. HARRINGTON, U. S. N., in the Chair.

A NEW METHOD FOR CARRYING AND LOWERING, AND FOR DETACHING BOATS; ALSO A SUGGESTION FOR DEFENDING SHIPS AGAINST AUTO-MOBILE TORPEDOES.

BY LIEUTENANT D. H. MAHAN, U. S. N.

Mr. Chairman and Gentlemen:—The models I wish to exhibit to you this evening I have spent a great deal of time and thought upon, but until now I have hesitated about presenting them.

I.—FOR CARRYING BOATS AT SEA.

My plan, which I hope will elicit the ideas of others, is so to carry boats on board ship that they may all be lowered, either on one side or the other, or on both sides, as the case may require. How to do this I will explain by experiments with my model. First, I have the arms in position to receive the boat as soon as hoisted. Let us hoist the boat to the davit-head. As soon as hoisted, men on the rail turn the cradles under the boat and the guys are set up. The boat is lowered into the cradles and hauled inboard, the falls being unhooked. Carrying the boat across the ship and hooking the other falls, we prepare to lower the boat by running the cradles to the outer ends of the arms and hauling taut the falls. (This is the position of the boat, if at sea and expecting to sight an enemy's fleet.) Two men on the rail unhook the brace bars. As soon as the bars have been lowered, a man stationed on deck, by bearing down on the triggers, immediately removes both cradles from under the boat, and the men on the rail turn the cradles alongside the ship in either direction. The boat can now be lowered.

The arms are raised into place by hooking the boat falls into the hook on the ends of the arms. Since the guys have not been let go, the arms will swing into position as soon as hoisted, and owing to the shape of the joints will catch of themselves. As soon as hoisted, the brace bars are hauled up into place. If it be desired to get a second boat out on the same side:—before hoisting the arms into place, hoist the cradles already on the arms inboard, and then hoist the arms into place and run the second boat out. In case of a ship in danger of foundering, there will be no necessity for hoisting the arms into place, but instead run the second boat out, steadying the cradles by the in and out tackles, and when the falls are taut, ease out and allow the cradle to go overboard.

My idea is to have the boat carriage and cradle made of paper, so as to reduce the weight as much as possible. If it be desired to change cradles, it can readily be done by removing the bolts which secure the cradle to the carriage. The carriages are secured at sea by wedging up, thus raising the rollers from the tracks and at the same time pressing the clamps of the carriage close against the under side of the track.

Description of Model—Plate I.

a, boat carriage and cradle, made in two parts and bolted together. The cradle depends on the style of boat used. The carriage is a simple oblong box, without a bottom. It has eight rollers inside of it, placed in pairs. There should be a bolt-ring at each end and in the centre of each side, used for tackles. The carriage has a clamp at each corner, passing under the track to prevent the carriage from tilting forward or aft.

b, outrigging arm forming a continuation of track. At the outer end there is an upright, *v*, which prevents the cars from running off the track.

c, track across ship, T-shaped. This track is supported by stanchions *t*; outboard of the stanchions the lower part of track is cut away to leave room for the wheel which is required to turn the cradles from the boat.

d, supporting arms for *b*, moving around a bolt at *f* and at *g*, hinged at *e*.

e, hinge.

f, bolt.

g, a movable collar working on *h*, self-adjusting when raising or lowering arm *b*.

h, upright bar, resting in casting step *i*, passing through casting *k*, and having wheel *n* secured to its upper end.

i, casting secured to ship's side.

k, casting secured to ship's side.

m, support for inner end of arm *b*, having a bolt passing through the sides of *m* and through *b*. This support is secured to *h* just clear of *k*.

n, wheel secured to head of *h*, used to revolve that bar.

o, on one side shows position of pin on which the brace bar *p* rests; on the other side, how the brace bar is cut to rest on the pin.

p, brace bar, intended to prevent the hinge *e* from giving away unless intended. These bars have to be removed before the cradle can be lowered.

q, line leading from near hinge *e* to head of lever *s*. This line breaks joints as soon after the brace bars are lowered as desired.

s, lever intended to tauten line *q* when breaking joint *e*, thus allowing arm *b* with carriage and cradle to drop from under boat. There are two levers, one to each arm, so placed on a bar running fore and aft that a movement of one causes a corresponding movement of the other.

t, stanchions supporting tracks; there are other stanchions in amidships.

v, upright at end of track to prevent carriages from running off.

w, hook by which arm is hoisted into place again.

This model was conceived some years ago, but I had laid the drawings aside. Two years ago I was reading Commander Hoff's book on "Examples, Conclusions, and Maxims of Modern Naval Tactics," in which he writes as follows:

"Will not the lowering of torpedo boats just previous to an engagement be fraught with danger, by giving the enemy a chance to concentrate and ram you?"

"To get the boats into the water, speed must be reduced."

"Now, if at this stage either fleet attempts to get the torpedo boats into the water, the other fleet would have a great advantage if they bore down upon them at full speed and engaged them."

"Two fleets meeting at night . . . . your torpedo boats cannot be gotten into the water."

"Captain Rivet is of the opinion that no faster speed than 8 or 10 knots will be maintained during an action."

These passages determined me to perfect this model, as I knew

that I had the means for lowering and detaching a boat while the ship was making 11 knots. This apparatus I will describe to you, and will also read a few extracts from the report made upon it by a board of naval officers.

II.—Boat-detaching Apparatus.

The castings are made the same for all boats, but as they are only three inches wide, a dinghy would not be much encumbered by them. The theory of this detaching apparatus is, that a hook with its centre of gravity above and outside of the centre of motion is bound to fall if uncontrolled. The hook is one inch in thickness. The controlling bolt is one of my own designing, as I wanted one that would not slip out and that could not be entirely pulled out. The first condition is obtained by means of a detent operated by interior springs, which keep the detent out unless compressed by the drawing of the bolt through the hole when about to detach the boat. The second condition is obtained by expanding slightly the inner end of the bolt and making the inner edge of the bolt hole slightly concave. The working part consists of two pieces of light wire rope passing under the beading on the outside of the boat, and connected one to each bolt; the other ends are made fast to two handles on the inside of the boat in the stern-sheets. Pulling the after handle disconnects the after fall,—the forward handle controls the forward fall. The boat must be water-borne to disconnect in this way. I believe this to be the only apparatus which will disconnect one end at a time.

Permit me to introduce here a few extracts from the report.

"In order to give the apparatus a trial under circumstances as near as possible to those in actual service on board a sea-going vessel, the boat was hoisted to the davits of the U. S. tug Monterey, and taken to the entrance of San Francisco Bay, where a topping sea was met, in which she pitched and rolled heavily.

"While going at full speed, making about 11 knots, sea a little on the bow (same side as boat), the boat was lowered with bolts withdrawn, and immediately upon striking the water freed herself from the tackles. Before a second trial could be made in a sea-way, the boat swung inboard, owing to the absence of guys, and span upon the davits, was partially stove, and swamped by the unhooking of the forward fall, thereby preventing further rough-water trials.

"In smooth water the boat was lowered a number of times, both while at rest and going at full speed, in all of which cases she cleared

herself successfully. In all these cases the bolts or keys were withdrawn before lowering.

"The trial was then continued with the bolts or keys in place, properly attended and withdrawn at the word of command, after the boat was water-borne, with the same success as before.

"It is evident that the invention has several advantages, such as simplicity, cheapness, strength, non-liability of getting out of order or of being in any way obstructed by passengers, freight or boat equipment, facility with which the boat clears herself from the tackle when water-borne, and great ease in hooking on for hoisting in a sea-way.

"The principal disadvantages appear to be the necessity of lowering the boat square, or a little by the stern, and a careful attendance of the bolts so that they may be instantly withdrawn upon the boat striking the water, a difficult matter in moments of haste or excitement."

Now, the first of these disadvantages is common to all boats, as no one would lower a boat bow first with a ship moving ahead; the second appears no longer to be a disadvantage when the necessity of knowing the boat to be safe in the water before letting her go from the falls is considered.

Seamen differ as to when the boat should be let go, and some have said to me that my apparatus would be excellent were one able to detach the boat in mid-air. To afford no ground for such a complaint, I have had fitted to this boat an arrangement by which the boat can be detached in mid-air, and in putting it into the boat it is so arranged that the stern will start an instant before the bow, thus doing away with the necessity for lowering the boat square or a little by the stern. This mid-air arrangement can be taken out when in port, as there is then no necessity for its use. The hole for the mast is used, and the step for this little windlass can be used as a step for the mast.

With this addition to my detaching apparatus, I claim that a boat can be detached in any way and at any time that may be desired, and, moreover, with perfect security against accidental detachment. I can detach either end first, or both at the same time; either in the water or in the air; with the ship lying dead in the water or going at full speed; and with the boat loaded or empty. Everything connected with the apparatus is above the line of thwarts and all parts are easy of access. Then, again, you can get into the boat and play with the apparatus and it will not go off. If, while a boat was being lowered with bolts withdrawn, a sea should strike near the bows, both ends would unhook. If this should not happen—if the bow

only unhooked—upon letting go the after fall, the boat would free herself.

The following experiments have been tried successfully:

1. Disconnecting both ends when water-borne, no one in boat.
2. Disconnecting bow when water-borne, no one in boat.
3. Disconnecting stern when water-borne, no one in the boat.
4. Disconnecting both ends when in the water, a man attending the bolts.
5. Disconnecting bow when in the water, a man attending the bolts.
6. Disconnecting stern when in the water, a man attending the bolts.
7. Disconnecting in mid-air, both ends.
8. Disconnecting in mid-air to show that the stern starts first.
9. Stepping on bolt lines to show that bolts will only draw by a direct pull.
10. Swinging boat with bolts drawn to show that the apparatus will not detach by any motion of boat.

Description of Model—Plate II.

Fig. I. Shape of boxes as used in bow and stern.

Fig. II. Shape of boxes when placed more towards the centre of boat.

a, ring attached to lower block of boat fall.

b, hook,—its shape shows why it falls if uncontrolled.

c, hole for controlling bolt.

d, hole for bolt around which hook revolves.

e, hole for use in towing, being towed, or by means of which the boat could be suspended if desiring to overhaul detaching apparatus.

f, holes for riveted bolts.

Fig. III. Shows three views of controlling bolt.

1, bolt showing detent open, and flare of bolt.

2, bolt showing hollow for detent, slot in detent, shape of detent, and springs out.

3, same as 2, but with springs compressed.

m, head of bolt, showing hole where the line is fastened.

The mid-air detachment consists of a very small windlass placed on the after thwart, fitting through the mast hole and into its step. Two lines are led from the windlass, one to the forward hook, the other to the after hook, and fastened to the holes in the heads of the

hooks marked *x*. The after line is of such a length as to tauten an instant before the forward line. As long as the bolts are in the boat cannot be detached,—but withdraw the bolts, ship the lever and heave on the windlass, and a motion through an arc of 20° will detach the stern; through 30°, the bow.

III.—Proposed Defense against Auto-mobile Torpedoes.

In proposing this protection I would like to say that other protection would be necessary against large torpedo boats, this one merely protecting the ship from auto-mobile torpedoes. The combination of two spars, one for the head and the other for the foot of the netting, will keep the netting in place even while going ahead. The nettings are continuous, from well ahead to well astern on each side, and are made in sections of from twenty-five to thirty-five feet. The spars are fitted with guys forward and aft; with distance chains, so that they cannot fall farther than intended; and with chain running from one spar to the other, which facilitates rigging in and out. To the ends of the upper spars are secured the boat falls, or a runner with fall inboard, if in way of gun, the hauling part leading to steam winches on upper deck. To the outer end of each of the lower spars leads a single line, passing through a block at davit's head, and used for easing out the lower spar until the chain between the two spars is taut, and also, if desired, for hauling the lower spar close alongside when hoisted sufficiently by the falls.

Suppose now that the nettings were down and it was desired to get under way. Start all the steam winches, and in five minutes the nets would be clear of the water, the upper spar would be perpendicular, and the lower spar so much raised that the net would be nearly horizontal and above the guns. If not clear enough, rig in the lower spars, allowing the netting to bag between the two spars and lie close alongside the ship. Lowering the netting on either side, in case a torpedo should be observed approaching, can be easily accomplished, and will retard the speed but little. The spar castings *a* are the only stationary parts; the spars themselves can either be unshipped or the longer ones be used for awning stanchions.

Description of Model—Plate III.

AB, water line.

a, castings for netting spars.

b, castings for heel of davits.

c, sleeves for davits.

d, spars for head of netting.

e, spars for foot of netting.

These spars *d* and *e* should be fitted with universal joints. The guys secure half way out. The setting up of the netting from forward guys the outer end of the spars.

m, falls leading to winches.

n, whip to trice in lower spar.

o, heavy thimbles for lashing or hooking sections of netting together.

PLATE I

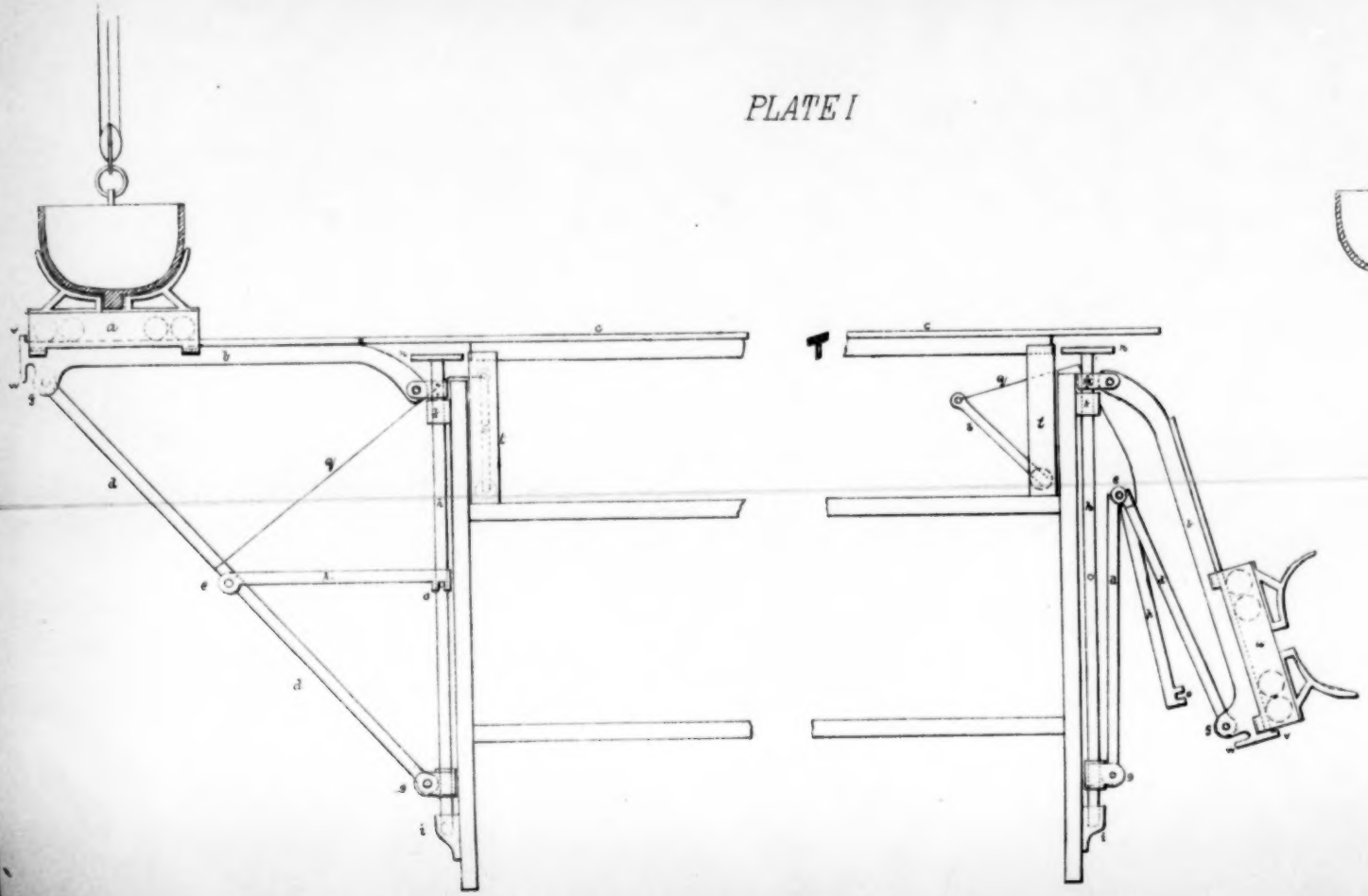


PLATE II

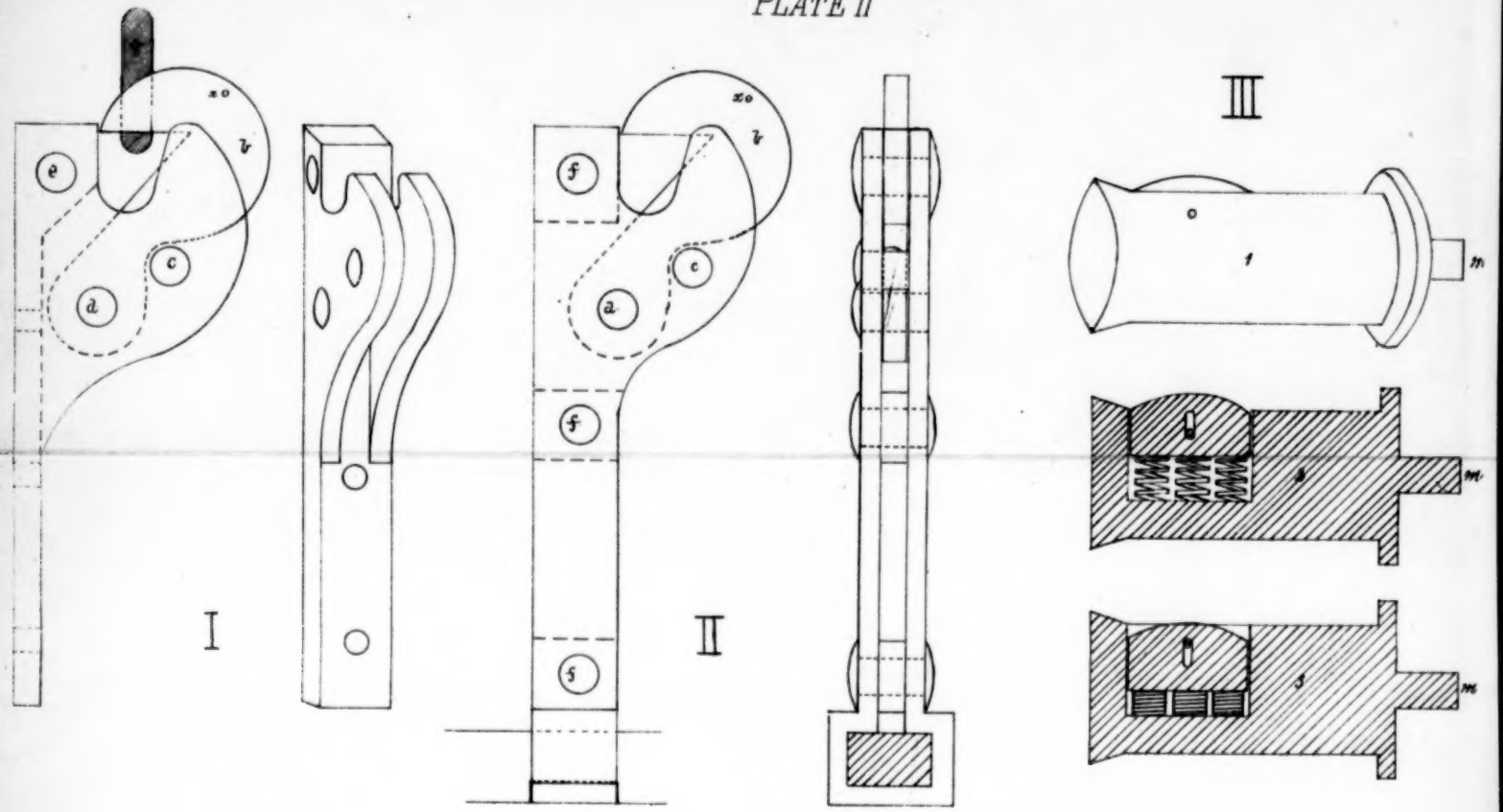
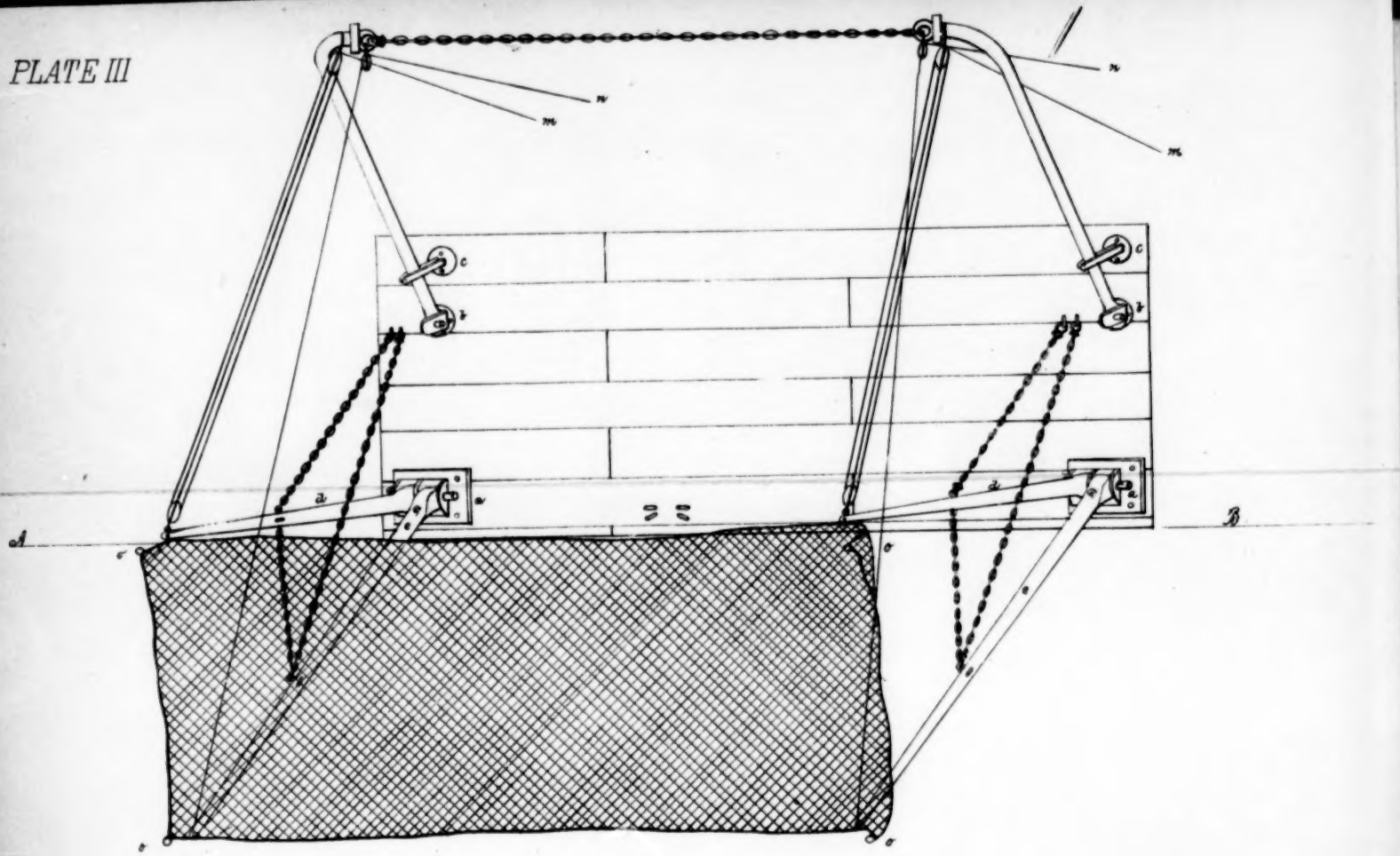


PLATE III



[COPYRIGHTED.]

U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

JUNE, 1887.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XIV.

Under the title of "A Remarkable Explosion," Prof. L. R. F. Griffin describes, in the *Popular Science Monthly*, **30**, 810–814; April, 1887, the circumstances attending the explosion by a stroke of lightning of one of Laflin and Rand's magazines at Brighton, Ill., August 29, 1886. The magazine was one of a group of eleven, standing on a comparatively open area of some forty acres, and it contained at the time of the explosion fifty tons of black powder and fifteen tons of dynamite.

The shock of the explosion was felt in Chicago, seven miles distant, as a sudden jar followed by a dull thud like that produced by a distant gun of large size. It was sufficiently violent to shake buildings six miles distant, so that, although a very severe thunderstorm was occurring at the time, guests in some of the hotels rushed frantically down-stairs, suspecting an earthquake. Plaster fell in the Immanuel Church, more than five miles away, so that it was at first supposed to have been struck by lightning, and a large plate-glass window in the Board of Trade building, about seven miles distant, was cracked, and the clock on its tower was put back three seconds. Examination of the locality of the explosion showed that the brick walls of the magazine had been pulverized and scattered over a wide area; the limestone foundation was torn up and a large part of the material

*As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address Torpedo Station, Newport, R. I.

broken into small pieces, the most of it carried through the air from forty to eighty rods; and a hole was torn in the ground, there mainly tough clay, about one hundred and fifty feet long, forty feet wide, and from ten to twenty feet deep. All the buildings in the immediate vicinity were demolished, while those which stood within reach of the flying stones were more or less riddled. The loss of life was very small considering the extent of the damage, only one person having been killed outright, although several others were severely injured, of whom some have since died.

Such are the primary facts of the explosion itself. An examination of the ground in the vicinity, and of many of the buildings ruined near by, together with others at considerable distance more or less injured, developed certain minor facts that bear upon the general subject of explosions. Especially do they seem to show that such explosions may produce an earth-wave which may do damage at great distances, the undulation of the ground displacing objects, cracking walls, and shattering glass, much like an earthquake in miniature. Sometimes this may possibly prove the source of the principal destruction.

Looking directly at the destruction itself, the results of the explosion appeared as follows: The buildings nearest the wrecked magazine were all crushed together, and, so far as could be determined from the ruins themselves, were pushed away bodily from the demolished building for a short distance, not more than one or two feet. This shows that the explosives instantly produced a very large volume of gas, which forced itself against the surrounding air and condensed it very quickly, until it gave way in the direction of the least resistance, which would necessarily be upward. This condition was confined to a small circle; for, while such a condensation would produce a wave of air, the mass bodily displaced must be confined within comparatively narrow limits. Displacement would not appear beyond.

Fortunately, at Brighton, no other magazine stood within this area, so that the dynamite in the others was unaffected by the shock, while the rain prevented the fire from spreading by means of dry powder. Outside of this area there was a narrow ring or circular strip of ground, with a radius of not far from fifteen rods, where comparatively little injury was done. One or two magazines stood in this region, and they escaped almost without injury, only being slightly battered by flying stones. Here the air was not moved as a

mass either way. The changes of density to which it was subjected were of the nature of molecular movements rather than motion of any great mass of air. Beyond that area the movement of the air was toward the point of explosion. This was shown by the forcing of the glass outward in all of the more distant buildings, while the walls of at least one dwelling-house and of several of the magazines left standing were thrown down toward the wrecked magazine. Furthermore, the roof of one magazine was clearly lifted and allowed to drop, besides being riddled with stones. These phenomena pointed clearly to diminished pressure of the external air, produced by the explosion, as is noticed in a small way when any gun is fired. Since most of the magazines stood in this region, no blow was struck upon them, and there was nothing to explode the dynamite stored within, else the first explosion would have been followed by others in a series and the damage multiplied.

These phenomena, taken together, seem to indicate the following as the steps by which the destruction was produced, though they followed so quickly that only delicate instruments would have distinguished them: First, the lightning exploded some of the black powder. The blow produced by this explosion detonated (?) the dynamite, tearing up the ground to make the hole, and breaking the foundation stone into small pieces. Then the rest of the powder exploded, sending the fragments away in all directions.

It is very strange that, when the danger from lightning is so well known—one of the same group of magazines was exploded by lightning in 1880—no precautions are taken by the owners for protection. The magazines are low structures, some of them roofed with slate, others with thin metal, in all cases very light, that they may offer but little resistance in case of explosion. The total neglect of precautions against lightning indicates a disregard of the known laws of electricity, or else the mistaken notion that a lightning rod, by furnishing a good conductor, attracts the lightning, and thereby increases the danger in place of being a safe path for the current. When such buildings stand upon level ground, in open areas, they necessarily become the path of any descending flash. If the electricity goes through the building, it becomes a source of danger, because it is likely to meet sufficient resistance to raise the temperature above the igniting point of powder, and it must be carried completely around the powder to insure safety. A network of metal rods carried over the tops of those whose roofs are slated, and given a sufficient ground connection, would

be a complete protection; it would carry away all the electricity, usually silently. To protect those with metal roofs, nothing more would be required than wide strips of metal from the roof itself to the ground. Of course, in either case, great care must be taken to prevent scattering powder on the ground within reach of electricity as it leaves the conductors. The problem of protection in this case has sometimes been compared with that of the protection of tanks in which petroleum is stored. This is a complete misconception. Protection of powder magazines simply requires a proper conductor to carry off the electricity, silently if possible, but so completely as to allow no escape in case of a flash. There are no complicating conditions, such as petroleum tanks present. Nothing, either in the material itself or in the air around, makes that a better conductor than neighboring objects. But in the case of petroleum tanks, gases are constantly rising from the petroleum and escaping into the air around, and particularly directly above. They frequently rise many feet above the tank, and experience proves that the gas, or the mixture of air and gas, is a much better conductor than the air itself. So the tank is likely to become the path chosen by every descending flash, and the problem of protection is not simply to furnish a conductor from the top of the tank, but one that shall conduct the electricity from the top of the ascending gas, always an uncertain height. So far no plan has proved completely successful.

The phenomena show clearly that two sources of danger arising from such terrific explosions must be guarded against. The glass broken within the first two miles proved a rush of air toward the destroyed magazine. The sudden uprush of gas, the mass being very highly heated, caused a vacuum, and the subsequent cooling added to the effect. The air rushed toward the vacuum from all directions, and when it was contained in a confined space, as a closed room, it quickly broke the glass, shattering it into small fragments, which fell outward. But the force which did this work was spent within a comparatively narrow area. Beyond that it only appeared as the back-and-forward movement of an ordinary sound-wave. The distance to which this was carried could not be determined, because beyond some seven or eight miles the report was not distinguished from the ordinary roll of the thunder.

This explosion produced an earth-wave as well as an air-wave. The force of the dynamite, exerted largely downward (?), not only tore the ground out to make a hole, but forced it away sidewise in all

directions. This formed a ridge around the hole, and at the same time it produced a wave, that is, an up-and-down movement of the earth. One observer, who was sitting quietly in a chair about six miles from the magazine at the time of the explosion, described the sensation which he felt as a quick movement down and up again. He was not quite positive which preceded, the motion upward or downward, but he thought that downward. That would indicate that the upward motion of the earth was first, since the human body has the sensation of moving in the opposite direction to the motion of the wave, and that agrees with the appearance of the hole. This earth-wave made dishes rattle in all places where it was felt perceptibly. In the central part of Chicago many plate-glass windows were cracked. These were injured by the earth-wave, not by the air-wave. They were simply shattered from the motion of the surrounding walls, but were not forced either inward or outward. One observer stated that a pane of glass near him was cracked at the moment when he felt the shock, not when he heard the report, which was a little later. This showed that the earth-wave moved faster than the air-wave which produced the sound. There is also reason to believe that this earth-wave travelled much farther than the air-wave. A self-recording barometer in the laboratory of Lake Forest University, about thirty miles distant from Brighton village, showed a sudden movement of the mercury at about that time, which could be accounted for only by referring it to the wave of the explosion. Probably this was not the limit of the movement. Unfortunately, there was no means of determining the rate at which this earth-wave moved. All these conditions combine to surround this remarkable explosion with peculiar interest.

The *Boston Herald* of June 6, 1887, gives an account of a new projectile, known as the Fannon-Winslow shell, which has been perfected by Massachusetts inventors. The idea of the inventor is to place three bottles containing the components of nitroglycerine in the interior of the shell, so arranged that they will crush and their contents mix when the shell strikes any object. Very powerful results are said to have been produced with this projectile.

A report of the trial of the Winslow shell by a board of ordnance officers will be found in the *Report of the Chief of Ordnance U. S. A., Appendix* 15, pp. 103–104, 1885. They describe the projectile as

being formed, like a Butler shell, with an appendage resembling a cascabel. The neck of the appendage, to which a wrench is fitted, is hexagonal. The part corresponding to the knob is a cylinder terminating in a spherical segment. The projectile is divided into two sections. The anterior part is a cylinder with an ogival head, and contains a cavity in which the ingredients to produce an explosive compound are contained. This section terminates at the rear end in a screwed tenon, by means of which it is fastened to the rear section. The rear section is provided with a cavity intended to receive a cast-iron plunger and a charge of rifle powder. Near the base of the projectile is a circumferential groove in which time-fuse composition is driven. This groove is connected with the rifle powder in rear of the plunger. An axial chamber is bored in the plunger and contains a small charge of rifle powder. The rear of this chamber is closed by a screw-plug, containing a vent filled with slow-burning composition.

The materials used for producing an explosive compound are glycerine and concentrated nitric and sulphuric acids. One pint of sulphuric acid and three quarts of glycerine were mixed in one vessel, and three pints of sulphuric acid and two quarts of nitric acid were mixed in another. A portion of the first mixture was placed in a glass jar, while a small jar placed within the first was filled with a portion of the second mixture. The liquid contents of the inner jar and of the outer jar when the inner one is inserted are equal in quantity, hence the proportions of the liquids are: sulphuric acid 2, nitric acid 2, and glycerine 1. The usual proportions, when nitroglycerine is manufactured by the ordinary processes, are about as follows: sulphuric acid 6, nitric acid 3, glycerine 1.

The jars are fastened together by screw-caps, and are placed within a tin cylinder, open at both ends, which fits the shell cavity. Stout cross-bars traverse the open end of the cylinder, and the exterior glass vessel is fastened to the bars by strong bands, which, aided by rubber straps, are designed to prevent the rupture of the jar when the piece is fired. The rupture is intended to be effected in the following manner: The time-fuse is cut at any point, and when the projectile has traversed a certain portion of its trajectory, the charge of rifle powder in the rear of the plunger is fired and the plunger is forced violently forward. This breaks the bottles, and, in connection with the rotation of the shell and the broken fragments, causes an intimate mixture of the glycerine and the acids, resulting in the form-

ation of an explosive compound. When the projectile strikes a resisting object, the shock of impact should (according to the report) cause the explosion of the compound thus formed, or, if this does not occur, then the charge contained in the axial chamber of the plunger will bring about the explosion.

The trial commenced April 23, 1885, when a shell was fired over water from an 8-inch muzzle-loading rifle with 35 pounds of powder. It could not be ascertained whether or not an explosion had taken place, for from the fragments that struck near the gun it appeared probable that the projectile had been broken up by the shock of the discharge. A second round was fired over land with 30 pounds of powder, the fuse being set at five seconds. The shell burst in the air in two and one-half seconds, and from the peculiar appearance of the smoke the rupture was regarded as due to the explosion of a substitution (?) compound. In the third round, fired with a 30-pound charge, over water, no explosion took place. The fourth projectile was exploded by means of an electric primer in an inclosure. The shell broke at the screw-thread into two pieces, the head being thrown some 25 feet out of the inclosure. The bottom was forced against the side of the inclosure.

In conclusion the board report that the acids can be safely transported to any point, the mixture can be effected without danger, and a shell arranged to contain them may be fired from a gun without injury to it. With the mixture used an explosive compound is probably formed, although the proportions of the ingredients used were not such as to give the best results. If they had been, and if the greatest possible amount of nitroglycerine producible by the ingredients which the shell cavity could contain were formed, it is not thought that the effect would be equal to that resulting with an ordinary bursting charge of gunpowder. The board therefore recommend that no further trials be carried on with this device or with devices closely resembling it in principle.

This same volume of the Reports of the Chief of Ordnance contains, on pages 57–59, a report of the tests of the 6-inch shells on the Snyder system* charged with dynamite. The board conclude that it is impracticable to fire shells containing commercial dynamite from a smooth-bore gun when a suitable powder charge is used under this

* Proc. Nav. Inst. **12**, 617; 1886.

system, and although previous experiments by the board have indicated that explosive gelatin can be successfully fired from an 8-inch rifle with a charge of 40 pounds of powder,* and therefore could be safely employed in this case instead of commercial dynamite, yet they do not consider that any trial with it in this system would be of any value, because the projectile employed possesses little penetrative power, and, furthermore, the system is very complicated and expensive. The board does not recommend further experiments with it, since simpler and less costly methods promise greater and more valuable results.

On pages 79–80 of the above report is a description of "M. L. S. Buckner's Aerial Drop for Explosives," which is a method of using high explosives from balloons. The board state that the machine is ingenious, and there seems to be no doubt that it will work and drop its explosives at the fixed time to which the alarm-clock may be set. The machine has to be suspended from a balloon, and to be efficient would require a very accurate knowledge of the force and direction of the wind at different elevations, and, of course, at best could only be used under the most favorable circumstances, and when the wind was blowing in the direction of the object to be reached.

The *Army and Navy Register*, June 11, 1887, p. 380, states that Lieutenant J. W. Graydon (late U. S. N.) has devoted his attention to explosives, and has undertaken—

1. To charge ordinary shells with dynamite in such a way as to render it safe to fire such projectiles from heavy guns with service charges of powder.

2. To use dynamite and powder together in the charge, thereby obtaining an increased velocity without a corresponding increase of pressure in the chamber of the gun.

3. To produce a new explosive which shall be safer while at the same time very much more powerful than ordinary dynamite.

Last winter experiments were made at St. Petersburg with the shell filled with dynamite, and the projecting charges consisting of dynamite mixed with black powder. Four charges of the mixture of thirty-seven pounds each were fired from a 6-inch gun, Navy pattern, the shells containing 102 pounds of dynamite. The velocity was

* Report of 1884, Appendix 17.

1993 and the pressure 1736. Four service charges of thirty-eight pounds of powder, with 102 pounds of powder in the shell, gave a velocity of 1499 and pressure of 1724.

Graydon's method of charging shells was tested by a board of army officers at Presidio, Cal., in 1886. They reported, August 13: "We have witnessed the results of fifty-two shells filled with commercial dynamite fired with the service charge of powder from the 4½-inch siege gun, and they were all fired with perfect safety to the gun, with the exception of two, the results of which were lost on account of the fog. Every shell that struck the bank or cliff fired at (range 2200 yards) exploded by concussion, no fuse being required for the explosion. It is the opinion of the board that Mr. J. W. Graydon has solved the problem of firing shells with dynamite with perfect safety to the gun, and at the same time making explosion sure upon the impact of the projectile; and, pending a full and extended report upon the experiments, the board unanimously recommend that experiments be continued with the 8-inch rifle converted and the 15-inch smooth-bore."

Experiments on this method are to be made at Sandy Hook with the 100-pounder Parrott and 7-inch wrought-iron guns.

The *Revue d'Artillerie*, **30**, 530–538; 1887, reprints from the *Militaire Spectator* of Breda* an article on "The Use, in Germany, of Gun-Cotton for Charging Projectiles."

In 1883 Messrs. Von Förster and Wolff took out two patents—one for a process for preserving gun-cotton,† the other for the construction of a shell charged with this explosive. The process of preservation invented by Von Förster consists in plunging the gun-cotton, wet or dry, into ether for 15 to 20 seconds; there is formed on the surface a very thin, hard layer impermeable to water and of a yellowish-brown color, thus giving the gun-cotton the appearance of wood. Nitro-benzene or other liquid solvents of gun-cotton may be employed in place of the ether. This layer does not affect the explosive properties of the substance, but diminishes loss by flaking and cleavage, retards decomposition, maintains the humidity at nearly the desired point, and prevents the penetration of paraffine. However, this pellicle contains always some very small interstices through which

* Nos. 11 and 12, 1886, and Nos. 1 and 2, 1887.

† For a fuller account see Proc. Nav. Inst. **12**, 563–602; 1886.

moisture may escape eventually, but this imperfection may be neglected if the gun-cotton is properly stored. Gun-cotton, not coated and containing 25 per cent of water, loses all its water in a few days if it be exposed in a brisk current of air, while the coated gun-cotton, exposed under the same circumstances, is not reduced to the dry state in as many weeks. Besides, the layer is so thin that its combustibility does not constitute a source of danger. In the case of dry gun-cotton for use as primers, after the treatment with ether, the detonator canal is plugged with paper and the disk is dipped in melted paraffine. This forms a second impermeable varnish.

The projectile described by the second patent is of cast iron formed of two parts which screw together, the interior being filled with disks of compressed gun-cotton. At the base of the shell is a fuse which fits into the perforations in the disks. The shell is provided with an ordinary percussion fuse, and this is connected with the primer by a fuse composition, which may be either gun-cotton in fine grains or a mixture of this body with meal powder, or some other nitro compound in fine grains, either alone or mixed with meal powder. The patent does not state how the fuse is held in place.

The arrangements described have been chosen as the result of experiments made at Walsrode on the effect of the explosion of gun-cotton in free air. These experiments of M. von Förster's led to the following conclusions: the power of gun-cotton increases with the density; in the moist state it is more *brisant* than when dry; it is advantageous to produce the inflammation of the charge at the part furthest removed from the object to be destroyed; and, finally, a cavity so placed as to follow the axis of the charge favors its action.

It does not appear that the shell described above has been experimented with, and later experiments on the explosion of gun-cotton in free air do not appear to confirm the conclusions reached relative to the position of the fuse and the existence of the central canal. They have, however, sought to utilize existing projectiles by devising means for charging them through the eye of the shell. These efforts have led to the taking out of another patent in May, 1885, for a method of charging and for a special mode of fixing the detonator.

The gun-cotton is used in the form of prismatic grains obtained by breaking up the compressed disks. They place 200 grams of dry gun-cotton upon the charge of wet gun-cotton. When the charge is in place they introduce a mandril through the eye of the shell, thus forming a canal in the cotton for the detonator and fuse, and they pour

into this space melted paraffine having a temperature of 75° to 80° C. This paraffine fills all the interstices between the grains, and in solidifying binds them into one compact mass. The fuse is similar to the German percussion fuse, model of 1873. The plug is elongated and opened at its lower end; it encloses a capsule containing one gram of fulminating mercury, and is surrounded by a band and tube, both of caoutchouc. The whole arrangement is held in place by a screw. If they wish to obtain a retarded effect they use a longer plug and interpose a fuse composition between the exploder and the detonator. In order to assure intimate contact between the fulminate and the charge they place a 10-grm. disk of dry gun-cotton around the detonator, and protect it from the action of shocks by caoutchouc bands.

The shells are charged before being stored in the magazine, but the detonators and fuses are put in place at the time of firing. A brass tube, destined to receive the detonator, protects the charge up to this time.

In the spring of 1885 the German Government furnished the Walsrode factory with a 15-cm. gun for the trial of this mode of charging. They used lead-covered shells of 2.5 cal. model of 1869, weighing 27 kg. and having a capacity of about 2 dm^3. Each shell received a charge of 1.35 kilo. of gun-cotton, with 20 per cent of water in parallelopipedons 10 mm. on the side and 20 mm. long, and 200 grams of dry gun-cotton in cubical grains of 6 mm. on the side. They fired the charge of 1.5 kg. against a parapet situated at a distance of 70 m. The velocity, measured at 30 m. from the muzzle, was 245 m. Out of five projectiles no premature explosion was obtained. Two of them had been fitted with retarded fuses, and these produced deeper craters than the other three. The number of fragments was considerable, and their dimensions did not surpass some millimeters. A shower of fragments were thrown more than 70 m. to the rear.

They exploded a shell buried 1 m. in the earth and obtained a circular crater about 2 m. in diameter, 70 cm. deep, and of a capacity of 1.25 m^3.

M. von Förster replaced this method adopted for holding the detonator by another, which is not described, but which seems to have given good results. He pursued these experiments and proved successively all the elements of the proposed system. For this purpose they fired an empty shell furnished with an unprimed fuse,

and with damp gun-cotton in the detonator, and they found that the fulminate in the capsule was not exploded. Then loaded shells containing neither fuse nor capsule were fired. There was no explosion and the gun-cotton was recovered unchanged. Next loaded shells, fused but not primed, were fired with a velocity of 420 m. against a parapet of wood, and afterwards of iron. There was no explosion, but as the resistance was increased the shells were broken up as if empty, and sometimes, though not always, the gun-cotton was set on fire.

Finally, he experimented with shell completely charged, fused and primed. More than 200 projectiles of 8.8 cm. were fired with a velocity of 450 m. The ordinary shells charged with gun-cotton were thrown from the rifled 15-cm. mortar with a velocity of 200 m., and from the 15-cm. gun with a velocity of 400 m. These last two pieces also projected steel shells of 6 calibers charged on the same system. There was no case of breaking up in the gun, and the final explosion was always complete.

In the experiments in breaking up at rest they have counted for a cast-iron 8.8-cm. shell weighing seven kilo., 200 fragments weighing over ten grams each, and 600 weighing from one to ten grams. An 8.8-cm. steel shell weighing 6.64 kilo. gave twenty-three large pieces weighing altogether 2.26 kilo., and 127 small fragments weighing together 2.865 kilo. A cast-iron shell of 15 cm. and 27 kilo. produced 376 pieces of more than ten grams, and 828 pieces of from one to ten grams. It was noticed that fragments weighing less than one gram traversed boards 25 mm. thick.

A projectile of 15 cm. and six cal., containing 9.935 kilo. of gun-cotton, buried vertically in the earth, the bottom being 25 cm. below the soil, produced a crater four meters in diameter and 1.3 meters deep, and having a crater of 7 m^3. capacity. An eight kilo. petard gave a crater of 3.5 m. diameter, 1.5 m. deep and 6 m^3. capacity; with a charge of sixteen kilo. they obtained a diameter of 5.1 m., depth 1.56 m., capacity 12 m^3.

In November, 1885, the *Revista di Artigleria e Genio* announced that the German Government had adopted the Walsrode granulated gun-cotton for charging shells.

In 1882 the German artillery began on their side experiments on the use of gun-cotton for shells. These experiments were made primarily in order to determine the possibility of using large charges in projectiles for the 21-cm. mortar. For this they used cast-steel projectiles with thin walls, and they were five calibers in length.

According to an article in the *Militaire Spectator*, the torpedo shells for the 21-cm. mortar are made in two parts, a body and a head, screwed together. The charge is enclosed in a thin zinc or iron box, and is composed of disks of compressed gun-cotton 5 cm. thick and containing twenty per cent of water. The upper disk carries a cylindrical cavity which holds a primer of dry gun-cotton, and the latter is pierced with a detonator hole. When the charge is placed in the box a rod of wood is inserted in the detonator hole, and melted paraffine is poured in to fill the interstices between the disks. The box is closed with a metal cover pierced with a hole for the detonator. When the box is introduced into the shell the head of the latter is screwed on, and a hollow screw is inserted in the eye of the shell in order to hold the box in place, and at the last moment the fuse and detonator are inserted in the aperture in the screw. The use of disks admits of greater density of loading, the charge being about four times as great as when granulated gun-cotton is used; but, on the other hand, it requires that the projectile should be in two parts, and that special disks should be made for each caliber.

These projectiles have given good satisfaction, not only in the 21-cm. mortar, but also in the 15 cm. and the 28 cm. In the latter piece the shell is loaded with fifty kilo. (220 pounds) of gun-cotton.

The article is accompanied by valuable drawings, which cannot be reproduced here.

From the *Report of H. M. Inspectors of Explosives*, 1886, we draw the following account of two accidents which occurred in the manufacture of gun-cotton. In one of these cases an engine-fitter was heating a piece of cast iron which had originally formed the plunger of a hydraulic press, when an explosion occurred. The iron piston had a hole three-eighth inch diameter down the centre to within one-half inch of the face, when the hole narrowed to one-eighth inch, and it appears that a small quantity of unsuspected gun-cotton was present in the upper part of the hole.

The other accident was of a more interesting character. A workman was in the act of removing some gun-cotton from an acid centrifugal machine at Stowmarket, when it fired and burned his face. The accident was believed to have been due either to a drop of perspiration which may have fallen on to the gun-cotton, or more probably to the presence of a small quantity of oil, the oil can having been temporarily deposited on the cover of the machine, where some

of the gun-cotton may have come in contact with it. It was found on inquiry that two similar accidents had occurred previously at this factory, but had not been reported (as they should have been); and this led to inquiries being instituted as to the experience of the Government Gun-cotton Factory at Waltham. It appears that such accidents, viz. the "fuming off" of acid gun-cotton in or on removal from the centrifugals, were by no means uncommon, and these have been variously attributed to a drop of perspiration, to condensation of moisture either on the iron of the centrifugal or edge of the pot, or to the gun-cotton being wrung too dry, so to speak, and thereby becoming heated. The correspondence above referred to led to the institution, by the superintendent of the Royal Gunpowder Factory, of a number of experiments.

These experiments show very conclusively (*a*) that the presence of moisture or oil, even in minute quantities, is liable under certain conditions to produce ignition; (*b*) that such liability is sensibly diminished where mineral oils are used; and (*c*) that the liability varies to a very considerable extent with the temperature of the building.

It may be worth while to quote the following passage from a letter from Colonel Noble, Superintendent of Waltham Abbey, dated September 21, 1886, as bearing upon the subject:

"These accidents appear to occur much more frequently in hot than in cold weather. If the temperature of the air gets near 85° in the shade, the gun-cotton, after the acid has been wrung out in the machine, is very susceptible to ignition, and if a small drop of oil or a few drops of water get into it at this period it is almost certain to fume off. Instances have been known where the accident has been traced to drops of perspiration from the face of the man employed in emptying the centrifugal. You will see by experiments on the 8th and 13th September, that when the temperature was from 60° to 70° F., drops of water failed to ignite, but drops of oil or oil mixed with water never failed. One drop of oil was sufficient. On the 13th, while I was in the house, one of the centrifugals accidentally fumed off, igniting the gun-cotton in the machine next to it. The comparative frequency of these accidents at Waltham Abbey is mainly due to the very defective accommodation, which obliges the centrifugals to be worked in the same house in which the gun-cotton is purified by the boiling process."

"The Utilization of Waste Acids from the Manufacture of Gun-Cotton" is the title of an article by M. E. Allary, in the *Paint, Oil, and Drug Reporter*, **31**, No. 13, p. 9; March 30, 1887.

In the course of an examination of the waste acids from the manufacture of gun-cotton he made a number of experiments with this liquid, with the object of again using the acid for the manufacture.

1. *Simple Distillation.*—The acid used had a density of 58° B., and was filtered through quartz to remove the suspended flakes of gun-cotton which it contained. 100 kilo. gave:

10.077	kilo.	nitric acid of 50° B.
6.279	"	" " " 10° B.
82.302	"	colorless transparent sulphuric acid of 62 per cent.
1.342	"	loss.
100.000		

If the distillation is continued the 82.302 kilo. sulphuric acid of 62° B. will give 67.5 kilo. sulphuric acid of 66° B. The acids which were recovered in this way were of sufficient strength to be used again in the manufacture of gun-cotton; the nitric acid alone required a slight bleaching. By carefully conducting the distillation an acid of 48° B. can be directly obtained.

2. *Distillation over Saltpeter.*—Starting out on the assumption that, in the ordinary method of preparing nitric acid, the sulphuric acid might be replaced by the waste acids, and that on account of the increase of nitrogen oxides (the average quantity of which had been determined) a stronger acid could be directly obtained, he distilled these waste acids over Chili saltpeter, and obtained at once an acid of 48.45° B., and when the saltpeter was previously dried, even of 49.4° B. In addition to this he obtained an excess of yield, which must be ascribed to nitric acid contained in the waste acids.

An engineer in the Government powder works near Brest, where gun-cotton is manufactured, on obtaining information of these experiments, raised the objection that small quantities of gun-cotton might be present in these waste acids and give rise to explosions. Repeated experiments, made with large quantities of the waste acids, have, however, shown that after decanting and filtering there is no danger in the further treatment of these acids. (*Bull. Soc. Chim.*)

The *Sci. Am.* **56**, 180; March 19, 1887, states that a number of experiments were conducted lately at the works of Messrs. Heenan and

Froude, Manchester, with a new explosive called "Roburite," which is manufactured in Germany, and is about to be introduced into this country for use in blasting operations. The composition and process of manufacture of this explosive are kept secret, but we understand that it consists of two non-explosive and perfectly harmless substances of such a nature that they may be stored or transported without special precautions or restrictions. These two substances may be mixed together when required, and, in combination, become roburite, a yellowish compound, which will bear rough handling with safety. We understand that an intense heat is necessary to explode it. In order to prove this, the explosive was placed, in the experiments in question, between two plates, which were freely rubbed together and hammered; and a small quantity thrown upon a fire was merely consumed, without exploding.

In order to obtain an idea of the explosive effectiveness of roburite, eight ounces of the explosive were placed in the centre of a plate of the very best steel and exploded. This plate was 3 feet square by half an inch thick, and a bulge of about 1 foot diameter and 3½ inches deep was caused by the explosion. Twelve ounces of the explosive were then placed on a cast-iron plate, 6 inches thick, weighing nearly three tons. After the explosion the plate was found to be broken transversely. Unlike dynamite, roburite is said to be in no way affected by varying temperatures, and if duly protected against damp, it may be kept for years in any climate without its efficiency becoming in any way impaired. It is also claimed by the manufacturers that roburite has an explosive force greater than dynamite by at least 25 per cent.

In exploding, roburite does not produce noxious gases, and therefore may be used without intermission, while the poisonous gases given off by dynamite often necessitate the stoppage of work, in some cases for a considerable time. This new explosive is applicable for use in mines and quarries, and for torpedoes and blasting operations generally. (*Industries.*)

Under the title of "Unsuspected Dangers with Frictional Electricity in Blasting," W. E. Irich narrates, in the *Scientific American Supplement*, **23**, 9172; January 1, 1887, an incident which occurred some years ago, and which nearly resulted in a most serious calamity, through want of knowledge regarding the power of induction.

About a week after the commencement of a long series of experi-

ments, several charges of gunpowder, gun-cotton, and dynamite were submerged in a river, about one hundred feet apart, the object being to learn what the effect of each would be when fired under the same conditions. The firing station and the position of the charges in the river were on this occasion totally obscured from each other, and about one mile apart. The cable employed to connect the charges with the firing apparatus consisted of a stranded copper wire well insulated with "Hooper's compound." Two lines were used for firing the charges, and a third or special cable of the same description was laid for communicating between the two points by telegraph. The three cables were laid on grassy land, parallel to but separated from each other by a space of a few inches throughout the greater part of their length. Electricity for firing the charges was obtained from Baron Von Ebner's ebonite-disk frictional machine.

The two ends of the cables at the river were each connected to a charge, while at the firing station one of the ends was carefully sealed and suspended in the centre of the firing room as a precaution and guard against the possibility of its coming in contact with the firing battery or machine. The other end was connected to the electric generator in connection with the charge to be fired first.

Final arrangements having been completed and all made ready, instructions were telegraphed to fire No. 1 charge, which was carefully and correctly done. Scarcely, however, had the firing key been depressed when word was wired from the river "to stop further operations, and leave everything at the firing station in the exact position it then occupied, as two charges had been fired instead of one only, as directed, and that in consequence a boat and a party of men engaged near the charge had most miraculously escaped being blown to pieces." This was declared by the operators at the firing station to be impossible through any action or neglect on their part.

The matter, however, was too serious to be left without a thorough and searching investigation. There was no question as to the second charge having been fired, and a careful examination of the cables between the points immediately after the occurrence failed to show the slightest sign of their having been tampered with. The evidence tended to locate the cause at the firing station, but how or by what means the charge was fired was quite unaccountable to all, and remained a matter of conjecture for several days, as the spare end of the cable had remained securely sealed and suspended, and was at the time of firing many feet away from the electric generator. A

very careful examination and insulation test of the end of this cable in the firing station proved that it had not been injured or tampered with in any way.

Experiments and investigation led eventually to the discovery of the fact that the firing of the second charge was due to induction. To remove all doubt of this, and for the information of all concerned, two half miles of the same description of cable were placed one foot apart throughout their entire length, fuses being connected to the cables at one end to represent the charges, and the wire being then grounded as before. To one of the cables at the firing station the frictional machine was connected, while the other end was carefully sealed and suspended in the same room as before, and at least ten feet away from the generator. The disks of the machine were given twenty revolutions, and the condenser was discharged, when both fuses fired. Other tests were then made, as given in the following table, to discover the greatest distance through which this inductive action would fire a charge, the wires being arranged as described above:

Distance of cable apart in feet.	No. of revolutions of the disk.	No. of charges fired.	Distance of cable apart in feet.	No. of revolutions of the disk.	No. of charges fired.
6	20	2	20	30	2
3	4	2	30	30	2
3	4	1	40	30	1
9	20	2	40	30	1
12	20	2	40	40	1
15	10	1	40	50	1
15	20	1	40	50	1
15	30	2	35	50	1
20	30	2	30	50	2
25	30	2	30	50	2

It would be dangerous on cables running parallel, and within forty or fifty feet of each other, to employ the frictional machine where more than one charge is connected.

It will be seen from the above table that a charge connected with a cable, one end of which was insulated, could be fired by the inductive action of another cable running parallel to and separated from it by a space of thirty feet when one class of electric generator was employed, whereas with a different generator the second fuse was not fired even when the cables were tied or twisted together, as will be shown by the following tests:

The frictional machine was now removed, and tests were made with dynamo machines and voltaic batteries, but in no instance was more than one charge fired, even when the wires were as close together as it was possible to get them, and then it was the one connected in circuit with the machine or battery.

These experiments clearly show that the detonation of the primary charge fired was not the cause of the second one exploding, and that the action was due to induction only. Had it been due to detonation, both charges would have been fired as readily by a dynamo machine or voltaic battery as with the static machine.

This power of induction could be put to good use, particularly in naval warfare, in firing and destroying the enemy's mines. It may also be interesting to note that, with a thirty-cell Grove battery and similar cable to the above, he succeeded in firing through a fault made by stripping off twenty-four inches of the insulation and submerging the bare wires in the sea. With an induction coil he failed to fire through a fault in the insulation only sufficient to expose the conductor to the eye. Wheatstone's magneto-exploder fired the charge through a leak one twenty-fourth of an inch long, but failed through a fault exposing one-eighth inch of the conductor. Siemens dynamo machine fired the charge through a leak exposing a surface of three-tenths inch, but failed to do so with a larger fault. Von Ebner's frictional machine fired through a leak of four and a half inches of bare conductor. It also fired the charge through a perfect break in the conductor. A four-cell Grove battery fired through three-eighth-inch leak, but failed to do so through three-quarters inch.

In connection with this it may be interesting to note that *Nature*, 17, 50–53; 1877, in an article on "Modern Torpedo Warfare," in reviewing the results of some experiments undertaken in Denmark two or three years before, briefly says: "Another point was also noted. A current of electricity, if it emanates from a powerful frictional electric machine, traversing one of a bundle of wires, will induce a current in the other wires, and thus bring about the explosion of torpedoes other than that which the operator on shore desires to ignite."

We observe that it is not stated in either of these two cases whether or not experiments were made to prove that the insulation between the wires was perfect.

F. Raschig, *Annalen*, **230**, 212–221; 1885, accounts for the discordant results of the analyses of iodide of nitrogen by Gladstone, *Jour. Chem. Soc.* **34**, 1851, Stahlschmidt, *Pogg. Ann.* **119**, 421, and Bunsen, *Annalen*, **84**, 1, by the fact that the precipitate obtained by adding ammonia water to a solution of the iodide is decomposed by washing with water. Sesqui-iodamine, NH_3,NI_3 or NH_2I,NHI_2, is first precipitated, but it is converted during the process of washing into NHI_2 and NI_3. The latter compound dissolves in potassium cyanide, forming cyanogen iodide: $NI_3 + 3KCN + 1H_2O = 3CNI + NH_3 + 3KOH$. The iodide of nitrogen prepared from a solution of iodine differs in its properties from the iodide obtained from the action of ammonia on finely divided iodine. The latter compound is much more explosive than the former, as it is capable of exploding when moist. The composition of this substance has not yet been ascertained.

By reference to the *American Chemical Journal*, **1**, 4–9; 1879, it will be found that J. W. Mallet has already gone over the ground which Raschig has been reviewing, that he has pointed out precisely the same source of error in the work of previous investigators, and that he has determined the composition of the amide produced by the action of ammonia on finely divided iodine and which was explosive under water, and he found that when it was produced with great care at a temperature below 0° C., and by the use of the strongest ammonia water and well purified by washing with ether and alcohol, it had a composition corresponding to NI_3 or N_2I_6, but with weaker ammonia hydrogen was found in the amide.

Mallet proposes to use the higher formula in view of the general fact that the compounds of nitrogen in which this element behaves as a pentad are those in which instability is chiefly observable, and from noticing the proportions in which hydrogen and iodine have been found in these amides it seems fairly probable that the molecules of these explosive compounds contain two pentad atoms.

T. Klobb, in studying "The Compounds of Ammonia with the Metallic Permanganates," *Compt. rend.* **103**, 384; Aug. 1886, finds that a permanganate of silver and ammonia ($Ag_2Mn_2O_8.4NH_3$) may be formed by dissolving one equivalent of potassium permanganate in water at 10° C., saturating with cold ammonium hydroxide, and adding two equivalents of silver nitrate dissolved in ten times its

weight of water. A crystalline precipitate is formed at once which, when washed and dried, has the form of a violet powder, and is but little soluble in cold water, though more soluble in warm. It slowly decomposes on exposure, losing ammonia and leaving a solid residue. Heated brusquely it fuses and is decomposed. It detonates under the blow of a hammer.

The cobaltic dodecammonium permanganate $[CO_2](NH_3)_{12}(Mn_2O_8)_3$ is deposited as a black crystalline powder when concentrated solutions of one equivalent of luteocobaltic chloride and three equivalents of potassium permanganate are mixed. When dissolved in boiling water it crystallizes out on cooling in small brilliant black crystals having the form of cubes, octahedra, and modifications of these two. When these crystals are heated or struck they detonate.

As a result of further study of the "Diazo-compounds," P. Griess, *Berich. Berl. Chem. Ges.* **19,** 313–320; 1886, has succeeded in producing a number of triazo and tetrazo compounds. Among these is the metatetrazo benzene platinum chloride having the formula $C_6H_4.N_2(NCl)_2.PtCl_4$. This crystallizes in very small roundish yellow plates, nearly insoluble in cold water and alcohol, but decomposed with evolution of nitrogen when heated with these liquids. The dry salt explodes violently when heated. The gold chloride $C_6H_4.N_2(NCl)_2.2AuCl_3$ is obtained as an explosive precipitate consisting of microscopic yellow needles. These salts resemble the diazo compounds in their reactions.

R. Möhlau, *Berich. Berl. Chem. Ges.* **19,** 280–283; 1886, prepares "Nitrosophenol Hypochlorite" by dissolving 1 gram of nitrosophenol in 500 cc. of water, adding 5 cc. of hydrochloric acid, and then running in a solution of bleaching powder until a distinct odor of hypochlorous acid is observed. It crystallizes in slender yellow needles having the formula of $C_6H_4NO_2Cl$, explodes when quickly heated to about 70°, or when touched with a drop of strong sulphuric or nitric acid, and gives Liebermann's reaction. It reacts energetically with amines and phenols, is resolved into nitrosophenol and hypochlorous acid by alkalies, and when heated with dilute sulphuric acid is decomposed into quinone, hydroxylamine, and hypochlorous acid. Acetophenonoxime also unites with hypochlorous acid.

[COPYRIGHTED.]

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MAY 16, 1887.

PROFESSOR N. M. TERRY, PH. D., Head of the Department of Physics and Chemistry, U. S. Naval Academy, in the Chair.

ELECTRIC MOTORS.

BY F. J. SPRAGUE (Late Ensign, U. S. N.).

Commander W. T. SAMPSON, Vice-President, in the chair.—The subject of the paper to be presented to the Institute this evening is "Electric Motors," and the lecturer, Mr. Frank J. Sprague, formerly an officer of the Navy and a graduate from the Naval Academy in 1878.

It is but a short time since Mr. Sprague was a student in this laboratory,* and I recall with much satisfaction the interest he always manifested in the subjects taught in the department of Physics and Chemistry. He was always among the leading men in his class in all branches; it was here that he passed his otherwise leisure hours and often his Saturday afternoons. Although his success in the scientific work which he has adopted as his profession is due to his ability and untiring energy, yet, no doubt, his first taste for it and his first successes in its pursuit were acquired here.

The same may, doubtless, be said of a number of other graduates of the Naval Academy who have already attained places of distinction in the scientific world.

I can imagine that it must be a source of gratification to Mr. Sprague to stand in this lecture hall and instruct those who were once his teachers. Though it is not among the substantial rewards of his success, it is well calculated to satisfy a commendable ambition.

Prof. N. M. Terry, head of department of Physics and Chemistry, will preside during the lecture and discussion.

*The meeting was held in the Lecture Room of the Physical Laboratory, U. S. Naval Academy. —ED. COM.

Mr. Chairman and Members of the Institute:—In extending my thanks to you for assembling to hear some remarks on a subject of such new and growing interest as that of electric motors, I feel somewhat at a loss how to proceed, because the subject admits of such a variety of treatment. Feeling thus, I have come to the conclusion that perhaps I had better speak of the subject from the standpoint of my own personal experience and practice. I will try to set forth, at first, some of the simpler laws governing the construction of motors and operation of motors, then touch upon the general question of the transmission of power, and, finally, speak of the present and future development of this work.

If some of the truths seem too familiar, I beg you will bear in mind the absolute necessity of fully understanding their fundamental character, and the importance of always referring to them as a basis, if we would correctly explain the operation of a motor, or forecast its operation with any certainty.

In any part of an electric circuit the expenditure of energy is measured by the product of the current and the extreme difference of potential, or $W = CE$.

If this energy is partly expended in heat and partially recovered in useful work, we have the expression

$$W = w + HJ,$$

where H equals the heat lost per second, and J Joule's equivalent.

But if R equals the resistance of the circuit,

$$HJ = C^2R,$$

and we have $$W = w + C^2R,$$

or $$w = W - C^2R.$$

If an opposing electromotive force e exists, which in the transmission of power is the motor electromotive force, commonly called the counter electromotive force, it is evident that

$$C = \frac{E - e}{R}.$$

Hence $$W = E\left(\frac{E - e}{R}\right).$$

Substituting the values of C and W, we have

$$w = E\left(\frac{E - e}{R}\right) - \left(\frac{E - e}{R}\right)^2 R,$$

or $$w = \frac{E - e}{R}\left[E - (E - e)\right],$$

or $$w = e\,\frac{E-e}{R};$$

and we also have the ratio

$$\frac{w}{W} = \frac{e\left(\frac{E-e}{R}\right)}{E\left(\frac{E-e}{R}\right)} = \frac{e}{E}.$$

That is, the electrical efficiency of the circuit is the ratio of the motor electromotive force to the generator electromotive force, or of the counter to the initial.

All the energy which is delivered to the motor is expended in two ways—heat and work. Our object should be to have as little as possible in heat; as much as possible in useful work. The current which goes into the field magnets serves to excite them, but the current thus used in maintaining the lines of force in the field magnets may be expressed simply as waste heat, and is measured by the quotient of the square of the electromotive force by the resistance of the field coils. The current that flows in the armature is expended partly in heat. This is measured by the product of the square of the current and the resistance of the armature; hence the resistance of the armature should be as low as possible. All the rest of the energy of the current is expended in work. This work appears in three forms. One is driving the armature in the magnetic field and forming currents in the body of the armature, and will be greater or less according to the formation of that body. Another expenditure of this work is the overcoming of friction of the armature bearings. The third is useful work.

Two distinct theories have been advanced for the proper construction of motors. The one is advocated by Messrs. Ayrton and Perry, and is to the effect that different general principles should govern the construction of dynamos and motors: that in the former the field moment should greatly predominate over that of the armature, while in motors the moment of the armature should greatly predominate over that of the field.

On the other hand, Professor Rowland, Dr. Hopkinson, Messrs. Mordey and Kapp, and I, hold the opinion that the best apparatus for converting mechanical power into electricity must necessarily be the best apparatus for converting electricity into mechanical power, and that the principles governing the electrical construction of one must be also the best for constructing the other. In short, in motors as well as in dynamos, we should aim to have the most intense

magnetic field possible, and the greatest ratio between the magnetic moment of the field and armature which the construction of the machine will permit. It is true that the great varieties of work demanded of motors make their construction often different from dynamos, but this does not affect the truth of the principle involved. So many practical as well as theoretical reasons exist for this view that I cannot see how any doubt can long exist of its soundness, and the fact exists that the most extensive and numerous developments of the transmission of power are made on these lines. Some of the reasons for adopting this view will appear as I proceed.

A motor when running may be considered as a dynamo machine propelled by a current: it has a field magnet like any other dynamo; it has an armature situated in that field, which, either because of the attraction and repulsion of the lines of force, or of the double attraction and repulsion of the poles which are set up in the armature acting on the poles of the field magnet, is caused to rotate. This armature rotating in the magnetic field has an electromotive force developed in it which is precisely of the same kind as would be developed were the motor driven by a belt instead of by a current. The strength of this electromotive force depends upon the resulting strength of field and the speed of the armature. This electromotive force, which may be termed a *motor* electromotive force, is ordinarily called the counter electromotive force, because it is opposed to that of the line current which is flowing into the motor. The difference between this line electromotive force and that of the motor is termed the effective electromotive force, and determines, in combination with the resistance of the circuit, the strength of current which will flow in the circuit.

As I have stated, the province of the field magnet is to produce lines of force which shall pass through the armature. Since this is the fact, it is apparent that we wish to create as many lines of force as possible in the smallest space, with the least weight of metal and with the least expenditure of energy.

In considering, however, the way in which the lines of force can be created, we must take into account a great many elements. One is the character, mass, shape, and distribution of the iron which is used in the cores of the field magnets and in the pole pieces. Another is the mass, space, and distribution of the wire around the magnets. Not less important is the character of the armature body, the space taken up by the wire, and clearance outside of the wire. This mag-

netizing force is represented by the product of the turns of wire and the number of ampères flowing in these turns—in other words, by the ampère-turns; and it is absolutely immaterial, so far as the magnetic result is concerned in the creation of the lines of force, how this product is made up—that is, whether there are a few turns and a great many ampères, or a great many turns and few ampères. For instance, if it takes ten thousand ampère-turns to magnetize a field magnet to a proper degree, we can magnetize it with one turn of wire and ten thousand ampères, or one ampère and ten thousand turns.

When we consider the economy, however, then we wish to have the greatest number of turns and the least number of ampères. In the case cited, if we used ten thousand ampères and one turn, we would be using ten thousand times the energy to magnetize the field magnets which would be expended were we to use ten thousand turns and one ampère.

That form of iron which gives the least length of wire for one turn is of course the circular, and that is the form which I have adopted in the field magnets of most of my machines. When exciting a field magnet from lines of given difference of potential, the ampère-turns which will flow is dependent upon the cross section of the wire alone, provided the mean length of turn is not changed. In other words, if the field magnet is wound with a certain gauge of wire it does not make any difference, so far as the strength of the field is concerned, whether there be simply one turn of the length of say two feet, or whether there be ten thousand turns each of the length of two feet, because just as we increase the number of turns we increase the resistance and we decrease the current, but we leave the product ampère-turns, which we will call Z, the same. Economy, however, as I have said, determines that we shall use the largest number of turns which we can place practically in a given space on our field.

Having, then, determined the magnetizing force, we have next to consider what opposes the creation of the lines of force. In some very beautiful experiments made by Dr. John Hopkinson and published in a communication to the Royal Society of London, some elaborate tables were given, illustrated by a number of curves, which showed the magnetic property of about thirty-five specimens of iron and steel, and the strength of field magnets for different magnetizing forces. It was there shown that the best material for commercial purposes to be used in field magnets was pure wrought iron annealed, because it offered less opposition to the

creation of lines of force than any other material. This had been practically accepted as a fact before the publication of these experiments, but I know of none which are entitled to more consideration. The introduction of manganese, sulphur, silicon, phosphorus, or carbon means very radical changes in the qualities of the iron, more so than has generally been realized.

We may make some analogies between magnetic and electric circuits. The magnetizing force or the ampère-turns may be likened to the electromotive force which urges a current over a circuit. As in an electric circuit the current generated depends upon the resistance of the circuit as well as the electromotive force, so too in the magnetic circuit may we very properly consider that the formation of lines of force actually created depends also upon the resistance of the path. The resistance of this path depends upon not only the cross section of any space over which the lines of force have to pass, whether in the metal or in the air, but also upon the specific resistance per unit cross section of the material over which they pass, this being different for cast or wrought iron, and being very much higher than either for air. It also depends upon the length of the space. We would then suppose that the number of lines of force which are created would be the quotient of the magnetizing force by the resistance; but when we come to magnetize a mass of iron, we find that a totally different element comes into play, and this seems to be a force which we may liken, if you please, to a counter electromotive force in an electric circuit—that is, it is an opposition set up to the formation of lines of force, which increases with the degree of magnetization, and finally reaches such a point that it effectually bars any further increase of this magnetization. In other words, if we plot out, as was first done by Mr. Hopkinson, the characteristic of a field magnet, laying off as ordinates the number of lines of force created, and as abscissae the magnetizing forces, we have a curve which starts almost as a straight line from the origin at an angle to both the axes of x and y, but soon begins to curve and finally becomes almost parallel to the axis of x, or so lightly inclined to it that it becomes a straight line which would intercept the axis of x at a long distance to the left of the origin. This has been explained by considering the curve to be formed of two components, one expressing the lines of force due to the presence of the iron, and the other additional lines of force set up by the coils around the iron; that the first part of the characteristic curve is formed by the sum of the ordinates of both, and the latter

part of it simply by a slowly increasing ordinate expressing magnetization due to the coils around the iron.

I do not feel prepared here to say whether this theory is right or not. If the iron can be brought up to a certain saturation and not be increased any more, then it seems that the air surrounding the conductor may be brought up to a degree of saturation and no further saturation possible. If this is so, it follows that we would finally reach a point in the characteristic curve of either a mass of iron or coils of wire, or these combined, when it would become tangent to the axis of x, and no further increase of magnetization would be possible under any circumstances. Physical conditions, however, prevent our reaching this point, because before we would get to that we would burn the coils off our field magnet because of the great heat developed. It follows that with every different shape of field magnet, quality of iron, and distribution of mass, that an empirical formula must be derived to truly express the conditions of magnetization.

To express a value for the number of lines of force, we must in addition consider the inter-polar space. This is occupied by the mass of iron in the body of the armature, which ought to have at least the cross section of iron that is present in the core pieces of the magnet; and it is further important that the space taken by the coils of wire on the field magnet should be just as small as possible. In other words, the gap or space between the pole faces and the body of iron of the armature should be as short as possible because of the very high specific resistance of air.

Mr. Siebert Kapp, in a very excellent book on the electric transmission of energy, has given some formulas for dynamos and motors of wrought and cast iron, and of different forms. But, as he has pointed out, they apply only to low degrees of magnetization, and of course depend upon the quality of iron used.

Although the quality and dimensions of the iron masses in a motor are important, it will be found in practical experience that the resistance of the gap is a no less important feature, and I will cite an illustration showing the important bearing which it has on the construction of a machine. As I have stated, I differ radically from Messrs. Ayrton and Perry in the theory which should govern the construction of a motor. I have said the field magnet ought to be as intense as possible; that is, the greatest number of lines of force should be created that it is in our power economically to produce. The resistance of the armature should be as low as possible, and the magnetization of the

armature should also be as low relatively to that of the field magnet as possible. Suppose that a machine has wound on its armature four layers of wire, and that it has a further space for clearance equal in depth to the thickness of one of these wires. The total gap then may be said to be $5a$, a being the thickness of one wire. *The magnetic moment of this armature with any given radiation of heat per square inch of surface is fixed, no matter how it may be wound, and no matter what its power.* This magnetic moment is, of course, the product of the ampères by the turns of wire. Suppose, for example, this armature be stripped and then wound with one-half the turns of wire, the wire being of double the cross section of that first used. We will assume that the insulation always bears the same ratio to the cross section. The armature would now have one-fourth the resistance, one-half the number of turns, it would carry double the current, the heat radiated per square inch of surface would be the same, the speed would be doubled, the power would be doubled, but the ampère turns would be a constant; and so on in other proportions. Suppose, on the other hand, that the armature be intended for a certain horse power, and have a certain radiating surface, it would, with a given efficiency, have a certain resistance. With this fixed resistance, the cross section of the wire would be in direct proportion to the number of turns. Instead of using eight turns of a certain cross section, laid four deep, suppose we use four turns, keeping the resistance the same. The cross section of the wire would be one-half. The weight of the wire would be one-fourth. The room occupied by the wire would be one-fourth. The capacity of the machine would be the same. The heat radiated with any given current would be the same. The gap would be reduced in the proportion of 5 to 2, assuming that we leave the same clearance. Since, however, we use a lighter wire, we can use a smaller gap, because, having less weight, the wires will have less centrifugal force and a finer binding wire can be used. We have then this new condition of affairs: the resistance of the armature has remained constant; the heat-radiating surface constant; the capacity of the armature constant; the weight of the copper in the armature has been reduced 75 per cent; the number of turns has been halved; the gap has been reduced 60 per cent. If, now, our field magnet was not nearly saturated, the number of lines of force which appear will be about doubled, because of the reduction of the gap; and since the lines of force have been doubled, the counter electromotive force which is set up by the armature at the same speed will be

the same, although there are only one-half the turns of wire that we had in the first place. The magnetic moment of the armature will be one-half what it was. The strength of the field being doubled, it follows that the ratio between the magnetic moment of the field and of the armature will have been quadrupled. There will be less distortion of the lines of force, there will be less sparking at the commutator brushes, there will be less change of lead at the commutator brushes. In addition to this, we have double the strength of field without increasing the expenditure of energy in the field magnet; in short, we see that one of our main objects should be to make with the most intense magnet field the smallest possible gap, taking care, however, that the increase of lines of force which we desire will be obtained by the proper proportion of the gap and the energy expended in the field magnet coils.

One of the most instructive experiments, showing the value and importance of masses of iron in both the field and armature of a motor, is the following: Arrange the motor with a balanced lever of known length attached to the armature shaft, with accurate means of reading the pull in a direction strictly tangent to the circumference of the circle which would be described by the end of the lever. With fixed strengths of current in the field, vary the current in the armature by any of the ordinary controllable means, and take simultaneous readings of the pull. This will give a curve showing the *characteristic of the armature*, which is just as important as that of the field. Then, with known currents in the armature, vary the current in the field, and likewise note the current and torsion readings. These results will give a saturation curve of the field, and an investigation of the data will give some interesting facts about your machine.

Several years ago Professor Moses G. Farmer suggested that I would find it an interesting investigation to determine a characteristic of the effective strength of field magnets by determining the number of feet per second a conductor one foot long would have to move to develop an electromotive force of one volt at its terminals when moving in the active part of the field. I use this method continually in my investigations, and have deduced for this purpose the following formula for the Siemens form of armature:

$$\varphi = p \frac{b \times l \times d \times t \times r}{2750 \times v},$$

where b = number of blocks in the commutator.
l = length in inches of active part of pole pieces of field.
d = mean diameter in inches of the circle of revolution of a coil.
t = number of laps of wire in one coil.
r = number of revolutions per minute.
p = ratio of circle covered by the pole pieces.
v = total e. m. f.

Motors may be described as belonging to one of three different systems. First, those in which the field magnet is excited by a coil in parallel circuit with the armature; second, those in which the field magnet is in series with the armature circuit; and third, those in which there is a combination of these two circuits. There are in addition a very large variety of each of these classes, different conditions demanding different performance. Furthermore, similar machines may be placed upon three different kinds of circuits, their performances varying widely in each case. These three conditions are: First, the case of special transmission with varying potential and current; second, constant current circuits; and third, constant potential circuits. I will now briefly consider the action of these different kinds of machines on two classes of circuits: First, on the constant current circuit. If a series-wound machine be placed upon such a circuit, the same current passing through the field magnet, it will develop a constant torque, which torque is directly proportional to the strength of the field magnet and the armature. If the masses of iron are large, this torque will be directly proportional to the effective ampère-turns in the field magnet, and the work done will be directly proportional to the speed. If the machine be at rest there will exist a difference of potential at the terminals of the machine equal to the product of the current and the resistance of the machine. When running, however, an electromotive force will be developed in the machine, and the potential at the terminals of the machine will rise by this increment. The work done may be expressed by the product of this counter electromotive force and the current, or eC, and is independent of the resistance of the machine. The resistance, however, determines, in combination with the other elements, the total efficiency of the motor. The total energy expended is the product of the difference of potential existing at the terminals of the motor and the current

flowing, or EC. The efficiency then is $\frac{eC}{EC}$, or $\frac{e}{E}$, and the heat wasted $(E-e)C$.

When running at any particular speed, the work will be increased directly as the field magnet strength is increased. So also will be the economy. The heat waste with any given resistance in a machine under these conditions is constant. The direction of rotation of such a machine can be reversed by reversing either the armature circuit or the field circuit; if both circuits are reversed, then the machine will run in the same direction. For many classes of work this kind of machine is exceedingly useful, because it admits of a great range of hand control. If such a machine, however, be put on ordinary work, and this work be lightened up, the machine will run faster and faster, and unless the field is weakened or the brushes are shifted to check it, the speed will theoretically increase without limit. Every change of speed and every change of load is accompanied by a corresponding change in the potential which exists at the terminals of the machine. Moreover, on a constant current, the motors being in series with each other and with lamps, this continual variation of potential is apt to cause trouble on the circuit, especially if the machines are not automatic, since, as already stated, with any fixed field the torque is constant, the work done is directly proportional to the speed. The machine has the highest efficiency when running at the highest speed.

With shunt machines, however, the action on the constant current circuit is much different. Here the current is divided in two circuits, such division, when the motor is at rest, being inversely proportional to the resistances of the two parts of the circuit. With such a motor, the field is weakest when the machine is at rest, and its torque or rotary effort is also very weak. As the speed of the machine increases a counter electromotive force is set up, the potential at the terminals of the armature and field magnets rises, the current in the armature diminishes, and that in the field magnet increases.

There are two ways by means of which a constant current motor can be governed. One consists in automatically changing the counter electromotive force by changing the position of the brushes on the commutator to positions more or less removed from their normal one. To this objection is offered because the proper position for the brushes of any machine is at the points of least sparking. The other method consists in varying the counter electromotive force by auto-

matically weakening the field as the load is diminished, or strengthening it as the load is increased. Several methods have been proposed for doing this, generally by the action of a centrifugal governor, but I am now engaged on another system which promises better results.

On constant potential circuits the different classes of motors present other peculiarities. A plain series-wound motor, when there is sufficient iron in the field, has a torque proportional to the square of the current flowing through it. It is capable of exerting a great rotary effort and doing a large amount of work at a slow speed. The range of speed for different loads is, however, great, and the motor is entirely unfitted for ordinary work where steadiness of speed is an object; as the load is diminished the speed increases, and, if thrown off entirely, the motor will run faster and faster, the field continually growing weaker, and the armature all the time accelerating its speed in a vain attempt to generate an electromotive force equal to the initial.

A series motor has some excellent characteristics for work where great changes in speed and torque are desired automatically, these changes being varied inversely.

Since with any given strength of field the torque varies with the increase in the strength of the armature field, and with any given strength of armature the torque varies with the increase in field strength, it follows that with large masses of iron in the armature and field, the torque will vary with the square of the current, and the ratio between the field and armature moment will remain constant.

The following will show the law of variation of speed for a series motor within the limits of the straight line saturation on a constant potential circuit.

If R is the resistance of the armature, and f that of the field, then

$$C = \frac{E - e}{R + f}.$$

$$\text{Work} = e\,\frac{E - e}{R + r} = eC.$$

Work also equals speed multiplied by torque.

The ampère-turns in the field $= nC$. e must vary, then, directly as speed and the field strength; whence

$$\text{Speed varies as } \frac{e}{nC} \text{ or } \frac{e(R+f)}{(E-e)\,n},$$

that is, the speed varies directly as the motor e. m. f., and inversely as the effective e. m. f. or current.

But the torque varies as nC^2 and equals MnC^2, M being some constant. Hence we have: Work = Speed × $MnC^2 = eC$,

$$\text{or Speed} = \frac{e}{MnC};$$

but
$$e = E - C(R+f),$$

whence
$$\text{Speed} = \frac{1}{Mn}\left[\frac{E}{C} - (R+f)\right]$$

so long as the characteristic is a straight line.

On the other hand, the shunt-wound machine will run fairly well on a constant potential circuit. The field, being excited independently of the armature, is constant, and since the load varies with the motor electromotive force, and the field is constant, it follows that the speed must vary with e. The torque is proportional to the current in the armature, and the speed will be slowest with the greatest load and fastest with the lightest, that is, when $e = E$. The lower the resistance of the armature, the less the variation in speed, and if sufficiently low with a large ratio of magnetic moments, the motor will practically run at a constant speed.

It is with the third class of motors, when used on constant potential circuits, that the difficulties which are involved in the governing of a motor mostly disappear, and, without the use of any such apparatus as centrifugal governors or movable contacts, it becomes possible to satisfy the most exacting conditions, both as regards efficiency, steadiness of running, power to start under very heavy loads, and freedom from sparking.

I must now particularly request your attention to a seemingly paradoxical statement. In a motor with the armature and field magnet independently supplied, the work which the motor will do in a given time, its economy and efficiency, are all independent of the strength of the field magnet, provided the translating devices intermediate between the motor and whatever is the recipient of its motion are not limited as to the rate of transmission of the motor speed; and that in all cases where a motor is working on a constant potential circuit and not up to its maximum capacity, *but still above fifty per cent armature efficiency*, in order to increase the mechanical effect either of speed or power, or both, or to compensate for any falling off of the potential on a line, it is necessary to weaken the field magnets, instead of strengthening them, and vice versa.

The strength of the field determines the speed at which a motor

must run to get a required efficiency. With a given initial potential at the armature terminals, no matter how the load varies from the maximum allowed, the speed may be maintained constant by changing the strength of the field; such strength being diminished as the load is increased, and, vice versa, increased as the load is diminished.

These facts may be demonstrated as follows:

Let us consider the motor current as derived from mains having a fixed difference of potential, and the motor with its field and armature in shunt relation. In this case the armature runs with a velocity dependent upon the strength of field, the initial potential, the number of turns, resistance, etc., of the armature, and the load, and a counter electromotive force is set up which regulates the armature current. The higher the speed the greater this counter electromotive force. Let E be the initial and e the counter electromotive force, and r the resistance of the armature. The current flowing in the armature is then $\frac{E-e}{r}$. With a given armature and given field, e varies with the speed. The power at any given speed and strength of field varies with the current, and with any given current varies with the strength of field. The total work done is the product of the speed by the work per turn, and since the speed is as e and the work per turn as the current $\left(\frac{E-e}{r}\right)$, the total work done is expressed by $\frac{e(E-e)}{r}$. The efficiency is the ratio $\frac{e}{E}$. It will be seen that both these expressions—the total work done and the efficiency—are independent of any function of the field, but depend only on the initial and counter electromotive forces and the resistance of the armature, for any given value of e can be attained with any strength of field by attaining proper speed.

Considering the speed of machine constant, its field alone being varied, and differentiating the expression for work done, $\frac{e(E-e)}{r}$, we have $\frac{de}{r}(E-2e)$ as the rate of variation of work, which will have a positive value with de negative when e is greater than $\frac{E}{2}$.

It follows, then, that to maintain the speed constant with a current of constant potential under varying loads, when the load increases so that the speed would naturally decline, the field must be weakened,

the counter electromotive force diminished and armature current increased, so that the tendency to reduced speed shall be counteracted, and there shall be an increase in the mechanical effect—power. For a decreased load the field is strengthened, the counter electromotive force increases, the current decreases, the speed remaining the same.

To maintain speed or power constant under varying initial potential, if the potential at the motor terminals increases, these mechanical effects increase or tend to increase. By strengthening the field an increased counter electromotive force is produced, so that the increased power or speed, or the tendency thereto, is counteracted, and this counteraction may evidently be itself considered a decrease in mechanical effect, whether the regulation is performed simultaneously with the increase of potential or before or after such increase. If the regulation is performed simultaneously, with a gradual change of potential, there may be less change in counter electromotive force or armature current; but there is still the counteracting of the tendency to increased mechanical effect, which counteracting is itself a decrease of mechanical effect. For a decreased or decreasing initial potential, the field is weakened to counteract the decrease in mechanical effect which would otherwise occur, and therefore to produce an increased mechanical effect.

Hence, to change the speed or power of a motor on a circuit of constant potential, the speed or power is increased by weakening the field, which produces a decreased counter electromotive force and an increased armature current, and consequently the increased mechanical effect desired; and such mechanical effect is decreased by strengthening the field, and thus increasing the counter electromotive force.

In brief, then, this method of regulating shunt-wound motors consists in strengthening the magnetizing effect of the field magnet coils of the motor to decrease the mechanical effects, such as speed or power, or both, and vice versa, weakening such magnetizing effect to increase the mechanical effects, and under varying loads the speed is maintained constant by an inverse varying of the strength of the field magnet strength.

This may be accomplished in several ways, one by varying the field circuits by a mechanical governor which responds to any variation in the speed of the motor, or in hand-controlled devices. For automatic work, however, I prefer to make use of certain coils in series with the armature and dependent upon it, which coils have a resultant

magnet action which is opposed to that of the main coils of the machine. While the main principle is the same, I have a number of different ways of applying it which may be classed as the long shunt, the short shunt, the distorted differential with long and short and compound shunts, and the distorted cumulative-differential with long and short and compound shunts. The first of these was originally proposed by Professor Ayrton, but the proportion of his winding was not the same as my own, because determined experimentally and with field magnets whose magnetic moment was less than that of the armature, while in my motors the converse is true.

In the following demonstration, then, it is to be assumed that the field moment greatly predominates over that of the armature, and also that the characteristic is practically a straight line.

Let f denote the resistance of the main or shunt field coils; m the number of turns therein; r the resistance of the differential or series field coils, and n the number of turns; E the difference of potential at the shunt terminals; e the counter electromotive force set up in the armature; and R the resistance of the armature.

The work done $= e\frac{E-e}{r}$; that is, it depends upon e, a variable quantity, and upon the constants E and r.

Now e varies with the speed and field, or the effective magnetic moment of the field, but the conditions are that the speed remains constant, hence e must vary with the field alone.

Current in shunt field $= \frac{E}{f}$;

Magnetic moment of same $= m\frac{E}{f}$.

Current in series field $= \frac{E-e}{R+r}$;

Magnetic moment of same $= n\frac{E-e}{R+r}$.

The effective magnetic moment must then be $m\frac{E}{f} - n\frac{E-e}{R+r}$; and the conditions are such that (for two different counter electromotive forces or two different loads)

$$\frac{e}{e^1} = \frac{m\frac{E}{f} - n\frac{E-e}{R+r}}{m\frac{E}{f} - n\frac{E-e^1}{R+r}}$$

or, $$\frac{e}{e^1} = \frac{mE(R+r) - nf(E-e)}{mE(R+r) - nf(E-e^1)}$$

or, $$\frac{e}{e^1} = \frac{mE(R+r) - nfE + nef}{mE(R+r) - nfE + ne^1f}$$

or, $emE(R+r) - enfE + ene^1f = e^1mE(R+r) - e^1nfE + e^1nef.$

Cancelling, we have

$$em(R+r) - enf = e^1m(R+r) - e^1nf,$$

or, $$m(R+r)(e-e^1) = nf(e-e^1),$$

or, $$\frac{m}{n} = \frac{f}{R+r}.$$

That is to say, the number of turns in the shunt coil must bear the same ratio to the number in the series coil as the resistance of the shunt coil bears to the sum of the resistance of the series coil and the armature.

This is my method of winding for a machine of the kind mentioned, and so wound it will be self-regulating for any constant potential up to the maximum allowed by the construction of the machine, and from no load up to the maximum.

There is a feature of motors so wound which may be here noticed. The ratio of the magnetic moments of the shunt and series fields is

$$\frac{m\frac{E}{f}}{n\frac{E-e}{R+r}}, \text{ or } \frac{mE(R+r)}{nf(E-e)}.$$

But $$\frac{R+r}{f} = \frac{n}{m}.$$

Hence the above ratio $= \frac{mEn}{mn(E-e)}$, or $\frac{E}{E-e}$.

That is, the ratio of the initial to the effective electromotive force is the same as the ratio of the moments of the shunt and series coil.

When $e = 0$ this ratio becomes $\frac{E}{E} = 1$; that is, the moments are equal, and this means that, in a perfect machine, *if both coils be closed and in their normal position, for any potential or current, a zero field, or practically so, will be formed, and the motor will either not start at all, or if it does start will run at a very great speed, take the maximum current at any given potential, and do little or no work at all.*

In starting, then, it becomes necessary to cut out this governing coil, making the motor a pure shunt motor, or to reverse it and make it a cumulative motor. I use both methods.

What has already been pointed out may be again stated, that the motor will regulate itself perfectly for all potentials so long as we work with a straight line characteristic, *but it must be with a theoretical armature efficiency of not less than fifty per cent, for if we go below this, the governing coil works in the wrong direction.*

A better way of arriving at this same law is as follows:

When running absolutely without load the motor e. m. f. is E, and the field is that due to the shunt coil. When running with a load the motor e. m. f. is e, and the magnetic field that due to the difference of the shunt and series field moments. We have then, since we assume that our speed is not changed, the equation

$$\frac{e}{E} = \frac{\text{shunt moment} - \text{series moment}}{\text{shunt moment}},$$

or, subtracting each side from unity, we have

$$\frac{E-e}{E} = \frac{\text{series moment}}{\text{shunt moment}}.$$

That is, the effective e. m. f. is to the initial e. m. f. as the moment of the series coil is to that of the shunt coil.

But $$\text{series moment} = \frac{E-e}{R+r}\,n,$$

and $$\text{shunt moment} = \frac{E}{f}\,m,$$

whence, substituting, we have

$$\frac{E-e}{E} = \frac{\frac{E-e}{R+r}\,n}{\frac{E}{f}\,m}; \text{ or, } \frac{m}{n} = \frac{f}{R+r}.$$

Referring to this equation, we see that if a is the resistance of one mean turn of the shunt coil, and b that of one mean turn of the series coil, then $n = \frac{R}{a-b}$.

By varying a, and n to correspond, then the motor may be set to run at different determined constant speeds.

Now consider the same class of motors with constant speed, varying load, and *constant current.*

Let the resistances and turns be designated as before. Let K be the constant current. Let E be the variable potential at the terminals of the motor, and e the variable counter electromotive force.

The work done $= \frac{e(E-e)}{R+r}$.

We must eliminate E, making it dependent upon e and the constants R, r, f, and K, and hence the work can be expressed in terms of R, r, f, K, and e, of which e is the only variable quality; e depends upon speed and field, but speed is constant. Hence our conditions require that with the same current we make e, and hence the work, variable, but by changes in the field alone.

$$\text{Field current} = \frac{E}{f}.$$

$$\text{Armature current} = \frac{E-e}{R+r}.$$

But $K = \frac{E}{f} + \frac{E-e}{R+r}$,

or, $f(R+r)K = E(R+r) + fE - fe$;

or, $f(R+r)K + fe = E(R+r)fE$;

or, $\frac{E}{f} = \frac{(R+r)K+e}{R+r+f}$, and $K - \frac{E}{f} = \frac{fK-e}{R+r+f}$.

$$\text{Moment of shunt field} = m\frac{(R+r)K+e}{R+r+f}.$$

$$\text{Moment of series field} = n\frac{fK-e}{R+r+f}.$$

$$\text{Effective moment} = \frac{m(R+r)K + me - n(fK-e)}{R+r+f}.$$

Our conditions are such that

$$\frac{e}{e'} = \frac{m(R+r)K + me - n(fK-e)}{m(R+r)K + me' - n(fK-e')},$$

or, $$em(R+r)K + mee' - nfKe + nee' = e'm(R+r)K + mee' - nfKe' + nee'.$$

Cancelling and transferring,

$$m(R+r)(e-e') = nf(e-e'),$$

or,

$$\frac{m}{n} = \frac{f}{R+r},$$

which is the same law as found for constant potential.

The ratio of moments is $\frac{m(R+r)K+me}{nfK-ne}$.

When $e=0$ this becomes $\frac{m(R+r)}{nf}$.

But $\frac{R+r}{f}=\frac{n}{m}$; hence substituting we have $\frac{mn}{nm}=1$.

That is, if the motor is at rest and any current is sent through it, a zero field will be produced. This of course follows from what has been already said about the constant potential motor.

The potential E which will exist if $e=E$ and no current is passing in the armature is fK, and the maximum work is done when $e=\frac{fK}{2}$. To be self-regulating, the motor can be worked up to this point, but not beyond it, for then the regulating coil works in the wrong direction; but this method of regulation is useless for constant current circuits, as is evident from the low efficiency.

We will consider another variety of motor in which this series coil is placed outside the terminals of the shunt coil. The laws governing the action of this machine on a constant potential circuit may be deduced as follows:

Let the same letters of reference be used.

Then the potential existing at the shunt terminals will be $E=rC$.

$$\frac{E-rC}{f}=\text{shunt current};$$

$$\frac{E-rC-e}{R}=\text{armature current};$$

$$\frac{E-rC}{f}+\frac{E-rC-e}{R}=C;$$

$$ER-rCR+fE-rfC-ef=CRf;$$

or,
$$CRf+rfC+rRC=fE-ef+ER.$$

Whence,
$$C=\frac{f(E-e)+ER}{fR+(f+R)r}.$$

Work done
$$=e\,\frac{E-rC-e}{R}.$$

But since C can be expressed in terms of e and constants, the work can be also expressed in terms of e and constants.

$$m\frac{E-rC}{f} = \text{shunt current},$$

$$nC = \text{series current},$$

$$m\frac{E-rC}{f} - nC = \text{effective current}.$$

$$= m\frac{E-r\dfrac{f(E-e)+ER}{fR+(f+R)r}}{f} - n\frac{f(E-e+ER}{fR+(f+R)r}.$$

But our conditions are such that

$$\frac{e}{e^1} = \frac{m\dfrac{E-r\dfrac{f(E-e)+ER}{fR+(f+R)r}}{f} - n\dfrac{f(E-e)+ER}{fR+(f+R)r}}{m\dfrac{E-r\dfrac{f(E-e^1)+ER}{fR+(f+R)r}}{f} - n\dfrac{f(E-e^1)+ER}{fR+(f+R)r}}$$

or $$\frac{e}{e^1} = \frac{mE[fR+(f+R)r] - mr[f(E-e)+ER] - nf[f(E-e)+ER]}{mE[fR+(f+R)r] - mr[f(E-e^1)+ER] - nf[f(E-e^1)+ER]},$$

or,
$$\begin{aligned} &mEefR + mEefr + mEerR - merfE + \\ &merfe^1 - merER - enf^2E + enf^2e^1 - enfER = \\ &mEe^1fr + mEe^1fr + mEe^1rR - me^1rfE + \\ &me^1rfe - me^1rER - e^1nf^2E + e^1nf^2e - e^1nfER. \end{aligned}$$

Cancelling, we have

$$mfR(e-e) = nf^2(e-e^1) + nRf(e-e^1)$$

or,
$$\frac{m}{n} = \frac{f+R}{R}.$$

That is, the number of turns in the shunt main field bears the same ratio to the number of turns in the series differential field, as the sum of the resistances of the shunt field and the armature bear to the resistance of the armature.

This is my method of winding for a machine of this character, and so wound, the machine will be self-regulating for any constant potential and for any load up to the maximum allowed, and even with a resistance in circuit and with varying potential.

The same peculiarity exists in those motors which has been pointed out in connection with the first class of differentially wound motors, and this will now be described.

The ratio of the magnetic moments of the shunt and series fields is

$$\frac{mE - mr\dfrac{f(E-e)+ER}{fR+(f+R)r}}{\dfrac{f}{\dfrac{nf(E-e)+nER}{fR+(f+R)r}}}$$

or,
$$\frac{mE[fR+(f+R)r]-mr[f(E-e)+ER]}{f[nf(E-e)+nER]}.$$

If $e=0$, this becomes

$$\frac{mEfR+mEfr+mERr-mrfE-mrER}{f^2nE+fnER}$$

or,
$$\frac{mR}{n(f+R)}.$$

But $\frac{m}{n}=\frac{f+R}{R}$.

Hence the ratio becomes $\frac{mn}{nm}=1$.

That is to say, if a motor of this character is at rest and the series coil in its normal governing position, and the circuit be closed to the motor, a zero field, or nearly so, will be produced; for under these circumstances the magnetic moments are equal, and either the motor will not start at all, or, if it does start, will run at a very great speed, take the maximum current at any given potential, and do little work or none at all.

This motor with constant speed, varying load, and *constant current* will now be considered.

Let the turns, resistance, etc., be designated as before. E is the variable potential at the terminals of the shunt field, and e the corresponding counter electromotive force.

We must eliminate E and express the work in terms of e and constants; e depends on speed and strength of field, but since speed is constant, e depends on the field alone.

$$\frac{E}{f}=\text{current in shunt field},$$

$$\frac{E-e}{R}=\text{current in armature},$$

$$K=\text{current in series field};$$

and therefore,
$$K=\frac{E}{f}+\frac{E-e}{R};$$

whence, $$fRK = ER + (E - e)f,$$

or, $$\frac{E}{f} = \frac{RK + e}{f + R}.$$

Our conditions are

$$\frac{e}{e^1} = \frac{\dfrac{mRK + me}{f + R} - nK}{\dfrac{mRK + me^1}{f + R} - nK}$$

or, $$\frac{e}{e^1} = \frac{mRK + me - fnK - RnK}{mRK + me^1 - fnK - RnK};$$

or, $$emRK + mee^1 - fnKe - RnKe = e^1 mRK + mee^1 - fnKe^1 RnKe^1$$

or, $$(e - e^1)\, mRK = (e - e^1) fnK + (e - e^1)\, RnK$$

or, $$\frac{m}{n} = \frac{f + R}{R}.$$

This is the same law of winding that holds when a machine of the same class is used for constant potential; and the same remarks in regard to the zero field apply as in the former case.

Also, as in the former case, the speed for any given current can be varied by varying the resistance and turns or the effective turns.

From the foregoing demonstrations it follows that a motor of either class depending for its regulation on this differential winding will regulate with a constant current only when working at less than fifty per cent armature efficiency; and that the same machine with the same winding will regulate on a constant potential circuit only when working at over fifty per cent armature efficiency.

The laws above set forth are for pure electro-dynamic motors; if there is any permanent magnetism, as in hard cast iron, or where permanent steel magnets are used, the law of winding is modified in so far as the residual or permanent magnetism is the equivalent of an electro-magnetic moment; but in this case, too, there should exist a zero field if the governing coil is normally closed when the motor is at rest.

It should be remarked here that in practice the quality of commercial iron makes some departure from theoretical laws necessary.

As an instance of the effect of reversing the governing coil in starting, if a constant potential motor has the series coil reversed when

the full circuit is closed, there being margin enough on the field characteristic, we would have a field twice as strong as the strongest normal field, four times the strength when the motor is doing its maximum work per unit of time, and a momentary rotary effort eight times that existing when the maximum work is on. As soon as the speed comes up, if the governing coil is short circuited and then reversed, the motor will be self-regulating.

On some machines I take another step in overcoming, or rather counteracting, the distortion set up by the armature, by producing a distortion in the field magnets which is dependent on precisely the same current that flowed through the armature. I will describe one method only.

Main field-magnet coils are employed in shunt relation to the armature, differential field-magnet coils in series with the armature, and additional cumulative field-magnet coils, also in series with the armature. The main field-coils may be shunted upon the armature alone, or upon the armature and both the cumulative and differential series coils, or upon the armature or either of the series coils, the other series coil remaining outside the terminal of the main field shunt.

The object sought is to maintain the non-sparking points of the commutator cylinder constant by opposing the distortion of the magnetic field due to variations in the armature current by a counter distortion dependent upon such variations, whereby the magnetic resultant due to the armature and field magnet is unchanged, and the line of parallel cutting of the lines of force or point of least sparking is maintained in the same position.

In accomplishing the counter distortion of the field, the motor used is one in which the field-magnet cores extend in different directions from the field of force in which the armature revolves. The differential series coils are wound or arranged so that their greatest effect is produced on diagonally opposite parts of the magnetic field, and the cumulative series coils, so that their greatest effect is produced on the other diagonally opposite parts. The differential coils are arranged to have a greater magnetizing effect than the cumulative coils. A decrease of load, causing a decreased armature current, tends to shift the magnetic resultant of the armature and field magnet; but this also decreases the magnetizing effect of all the series coils, and, therefore, the parts of the field principally affected by the cumulative coils are weakened, and those principally affected by the differential

coils are strengthened, whereby a distortion of field is produced opposed to that produced by the decrease of armature current, and hence the magnetic resultant—the line of parallel cutting and the points of least sparking—remains unchanged. Thus no shifting of the commutator brushes is ever required, except on account of wear.

I will now consider, from both the technical and commercial standpoints, the different classes of circuits on which motors may be used.

First. Arc light, or constant current circuits, in which the current supplied to the motor is kept constant at a certain number of ampères, ranging from six to nineteen ampères in different systems. The electromotive force at the terminals of the motor varies with the load.

Second. Constant potential, or incandescent light circuits, in which the difference of potential at the terminals of the machines is kept practically constant while the current varies with the load.

Third. Circuits in which the current and the potential both vary, as is the case where there is an appreciable drop or fall of potential on connecting lines somewhat removed from the source of power of a constant potential system, and in cases of special transmission.

I am now operating on all classes of these circuits, but since, because of the small ampère capacity of the current on arc light circuits, any large power must require a great difference of potential at the motor terminals, and variations of power will cause sudden and great changes of potential, the arc light circuits are useful in conjunction with arc lights for transmission of small powers only, or for constant work.

In considering the transmission of power from a general central station as an industry, that is, in a broad and comprehensive way, and not as an adjunct to some system of lighting, and leaving out of consideration for the present special cases of transmission, which forms a class of work by itself, practical and theoretical considerations make it imperative that the constant potential method of distribution is the only safe and feasible one.

It must be borne in mind that I do not agree with those writers who hold that central station distribution in limited areas is confined to "small domestic industries." We have then to deal with large and small powers, varying and constant loads, and the necessity of absolute independence both in operation and regulation of each motor. Furthermore, the motors may be designed for different classes of work, some constant in speed, others variable, and so on.

The only existing constant current circuits are used primarily for

the operation of arc lights. At present, as I have said, these range in capacity from nineteen to six ampères. The unit of light which is required for general purposes necessitates an expenditure of about half a horse power of electrical energy. A greater expenditure would be extravagant. In order to keep the size of the conductors as small as possible, and to allow long extended circuits, the tendency is to reduce the ampères to the smallest number.

The conditions of an arc light probably will not allow this to go below about six ampères; the more ordinary unit is about nine and a half. The commercial conditions unquestionably will not permit in the future a much higher ampère capacity, because the size of the wire varies as the square of the current used. With a nine and a half ampère current, a motor to develop one horse power—supposing it to have an efficiency of eighty per cent—must have supplied to its terminals about 933 watts of electrical energy. In other words, there would be at the terminals of the machine an electromotive force of about 98 volts for each horse power developed. Suppose, now, we want to transmit one hundred horse power; it would then be necessary (if the motor be of the same efficiency) to supply to it 93,250 watts of electrical energy; and if it were on this 9½ ampère circuit we would have an electromotive force of over 9800 volts.

In practice, arc light circuits vary from, say, 1000 to 2500 volts. On a 1000 volt circuit about ten horse power could be recovered; on a 2500 volt circuit about twenty-five horse power. In other words, existing arc light machines, if devoted entirely to the transmission of power, are limited to the actual development, on even the largest machines in ordinary use, of twenty-five horse power; and if used in combination with light, there would be available on any particular circuit only a fraction of this. If we are going to deal with the transmission of the tenth of a horse power, or one-half, or even two or three horse power, and are willing to have the element of danger as well enter into these small transmissions, then we can work with an arc light circuit; but if we are going to transmit units of five, ten, fifteen, twenty, or twenty-five horse power, we cannot deal with the arc light circuit; it is utterly impossible.

In Boston we have recently put upon certain lines nearly two hundred horse power. Suppose this were supplied on 9½ ampère circuits. No less than eight circuits of 2500 volts each would be required, and probably more, because with units as high as fifteen horse power and this division of circuits, the law of general average could come into play in but a very limited manner.

These eight 2500-volt circuits represent the capacity of a 460 arc lamp station, and to deliver the power not a single lamp could be used at the same time. The constant current method of distributing power is the limited and unnatural method; the constant potential, the comprehensive and natural method. This is a fact entirely independent of the question of relative electrical potentials, because on the constant potential circuit we can work at 100, 1000, or 5000 volts, if we please. In short, electrical distribution follows much the same laws that hold in gas, water, and steam distribution.

We may now with profit consider some of the peculiarities which distinguish special cases of power transmission, some of the methods which may be used, and also certain economic problems which are of prime importance. We will first note the behavior of a series-wound motor having a constant torque or load per turn. The motor being at rest, as the e. m. f. of the generator is raised the current $\frac{E}{K}$ increases until the torque is great enough to start the motor against its load. A motor e. m. f. is now created, and the current becomes $\frac{E'-e}{K}$. As the e. m. f. of the generator E' is increased, this current $\frac{E'-e}{K}$ *remains perfectly constant* and equal in value to $\frac{E}{K}$, and the motor increases its speed in the ratio $\frac{E'-E}{E}$.

In considering special cases of transmission, that is, between a single generator and motor, the better method is to use a circuit of variable current and electromotive force, and here, too, plain series machines may be used. These, however, must be definitely related, and I will very briefly touch upon the theory of this method of transmission.

We have the condition that the same current passes through each field and armature. We also have the condition that the speed is constant but that the work is variable. Work may be expressed as the product of speed and torque, and since the speed is constant, it follows that the motor torque must vary directly as the work.

Again, the work may be expressed by the product of the motor e. m. f. e and the current C. Since the speed of the motor is constant, e must vary directly as the strength of the field, which, if of low saturation, will vary directly as the current, and if highly magnetized, will vary in a less degree.

If E is the e. m. f. of the generator, and K the resistance of the circuit,

$$C = \frac{E - e}{K},$$

and, as above expressed, we have

$$E \propto e \propto E - e \propto C,$$

and

$$\text{Work} \propto eC \propto C^2 \propto e^2 \propto E^2.$$

The dynamo being driven at a constant speed, E varies as the strength of its field.

If $m =$ the number of turns of wire in the dynamo field and n those in the motor field, then the ampère-turns, or magnetizing forces, are mC and nC.

It follows from what precedes that mC should vary with nC in the same proportion. In other words, *the characteristics of the generator and motor must be similar in character between the limits of variation of load.*

The efficiency of the circuit being $\frac{e}{E}$, we have the following law, *that the efficiency is a constant for all loads in the limit of automatic regulation.*

If the machines are of the same general type, then, when correctly proportional, *the ratio of their size should be the same as the efficiency of the circuit.*

It is as well to give here certain general laws concerning the transmission of energy on a complete metallic circuit without leakage, which may be expressed as follows:

First, with any given work done by a motor, loss of power on the lines, electromotive force at the terminals of the motor, and distribution, the weight of copper varies as the square of the distance. That is, if the distance is doubled with these given conditions, four times the weight of copper will be required.

Second, with the same conditions, the weight will vary inversely as the square of the electromotive force used at the motor. That is, if using double the electromotive force at the motor, it is necessary to use only one-quarter of the weight of wire.

Another way of expressing this is, that if the weight of copper is fixed, then, with any given amount of power transmitted and a given loss in distribution, the distance over which the power can be trans-

mitted can be increased in directly the same ratio as is the electromotive force; for example, if a thousand pounds of copper is required to transmit a given amount of power with a given loss, and it is desired to double the distance with the same weight of copper, then the electromotive force must be doubled.

Again, with the same cross section of conductor, the distance over which a given amount of power can be transmitted will vary as the square of the electromotive force.

These laws may be expressed in a formula which is of frequent utility in determining the condition on ordinary circuits, and has also a widespread application in special work.

Let l = distance between the generating and receiving stations in feet, plus the sag.

n = number of effective horse power to be delivered on the motor shaft.

E = electromotive force at the terminals of the motor.

v = number of volts fall of potential on the line,

$E+v$ being, of course, the electromotive force at the beginning of the line.

K = efficiency of the motor.

CM = circular mils of conductor.

An electrical horse power is 746 watts, watts being the product of current by electromotive force. Then for any horse power, a motor efficiency of a, and an e. m. f. of E at the motor terminals, we have the number of ampères equal to $\frac{746\,n}{Ea}$.

Allowing 10.5 ohms as the resistance per mil-foot of copper, the total resistance would be $\frac{21\,l}{CM}$.

From the above we have

$$v = \frac{746\,n}{Ea} \times \frac{21\,l}{CM}$$

or

$$CM = \frac{15{,}666\,nl}{Eva}.$$

Let me give you a practical illustration. Suppose we have a motor the efficiency of which is ninety per cent at 400 volts electromotive force and when developing ten horse power, and that we wish to transmit this ten horse power 5000 feet from a station, and elect to lose about nine per cent on the line.

Our initial electromotive force will be 440 volts, and we would have

$$CM = \frac{15{,}666 \times 10 \times 5000}{400 \times 40 \times .90}; \text{ or}$$

$CM = 54{,}396$, which is about equal to a No. 4 B. W. G.

Again, suppose we wish to transmit five horse power over a distance of one mile on a complete metallic circuit of 45,000 *CM*, allowing five per cent increase of length for sag, and no leakage. Suppose, further, that the initial line potential be 300 volts, and that we wish to have 250 volts at the motor terminals, it is required to find the commercial efficiency which the motor must have.

Transposing our formula we have

$$a = \frac{15{,}666\, nl}{Ev\, CM},$$

and substituting,

$$a = \frac{15{,}666 \times 5 \times 5544}{250 \times 50 \times 45{,}000} = 76 \text{ per cent.}$$

This formula is useful in determining what we cannot do, as well as what we can do. For example, if we made the condition ten horse power, all others remaining the same, the commercial efficiency of the motor would have come out 152 per cent, a most excellent machine indeed, and yet it is precisely this absurd thing that people practically say they will do in many of the statements which are made in relation to this subject. No science admits of more easy determination of conditions by plain and simple laws, and none brooks less violation of them.

In considering the transmission of power, a very curious fact may be demonstrated by a formula for determining the minimum cost of plant, where the amount of power at the generating station is practically not limited, and where there is no line loss from leakage, the line loss being measured simply by the fall in potential.

The cost of a plant of this character can be divided into four parts, that of the motors, the line erected, the dynamos, and the power plant, whether water or steam. I will assume that the cost of the dynamos and motors cost the same amount per horse power or other unit, no matter what the electromotive force used. While this is not strictly true, for all practical purposes, with large units, and speaking from the commercial standpoint, it is so. This being the case, for any given power the cost of the motor is a constant independently of the potential used. The greater the loss on

the line, the less the cost of the conductors, but the greater the cost of the generators. On the other hand, the less the loss on the line, the greater its cost, but the less the cost of the generating plant. It follows then that the least cost to the contractor is determined when the increment of saving in the cost of the generator is equal to the increment in the cost of the line.

We have for the size of the wire necessary to transmit energy on a complete metallic circuit without leakage, the formula already given,

$$CM = \frac{15{,}666\,nl}{Eva}.$$

If d equals the weight of one mil-foot of copper, then the weight per foot of our conductor would be

$$\frac{15{,}666\,nld}{Eva};$$

and the total weight for length $2l$—this l being of course the actual distance plus the sag of the wire—would be

$$\frac{31{,}332\,nl^2d}{Eva}.$$

If b is the cost in cents per lb. of copper in line erected, we have for the cost of the line, which will of course depend upon local conditions,

$$\frac{31{,}332\,nl^2db}{Eva}. \qquad (1)$$

Let E be the e. m. f. at the terminals of the motor; v the fall of potential; β the commercial efficiency; E' the e. m. f. of the generator, and n the number of horse power developed by the motor.

Then $\frac{E'}{e}$ = ratio of the watt capacity of the generator and motor, $\frac{n}{a}$ = energy delivered to the motor terminals, $\frac{(E+v)\,n}{Ea}$ = energy delivered to the line, and $\frac{(E+v)\,n}{Ea\beta}$ = the horse power delivered to the generator.

If K = cost in cents of the generators per horse power required to drive them, and L the cost per horse power of the steam or water plant, then the cost of the generating plant complete would be

$$\frac{E+v}{Ea\beta}\,n\,(K+L);$$

and the cost of the total plant when M is the cost of motor per horse power developed,

$$TC = \frac{31{,}332\, nl^2 db}{Evd} + \frac{(E+v)(K+L)\,n}{d\beta E} + nM, \qquad (2)$$

which, differentiated for a minimum with v as the variable, gives as a condition

$$\frac{31{,}332\, l^2 db}{v^3} = \frac{K+L}{\beta},$$

whence,

$$v = l\sqrt{\frac{31{,}332\, db\beta}{K+L}},$$

or, substituting for d its value .00000302705,

$$v = .308l\sqrt{\frac{b\beta}{K+L}}.$$

In other words, *with fixed conditions of cost and efficiency of apparatus, the number of volts fall to get the minimum cost of the plant is a function of the distance alone, and is independent of the total electromotive force.*

The value of this will at once become apparent. Suppose at some place where we wish to transmit a large amount of power over a considerable distance, the cost of the water plant, that is, of the turbines, sluice-gates, water-channel, building and shafting, should cost $50 per horse power; that of the generator $35 per horse power; copper, per pound, erected, 20 cents; and further, suppose our dynamos to have an efficiency of 90 per cent. Our formula then becomes

$$v = \frac{l}{70}.$$

If the distance be five miles, the number of volts fall in potential would be

$$v = \frac{5 \times 5280}{70} = 377 \text{ volts.}$$

If 500 volts be used at the motor, the e. m. f. at the generator terminals would be 877 volts; and if 1000 volts at the motor, then 1377 at the generator.

While this fall of potential is independent of the total electromotive force, this last of course determines in part the total cost.

A consideration of the above formula and the investment and cost per horse power in any particular locality will quickly determine the practicability of transmitting power by electricity rather than generation by a local steam plant.

The commercial efficiency of the circuit may be expressed by the equation

$$\frac{E\alpha\beta}{E+v}.$$

It follows that, *to maintain the same commercial efficiency and the minimum net cost of plant, the e. m. f. at the terminals of the motor and the generator must be increased in precisely the same ratio as is the distance.*

Let us look at the problem in another light.

Suppose with the costs of material as above given we want to get a net commercial efficiency of sixty per cent on a ten mile circuit, with dynamos and motors whose *couple efficiency*, $a\beta$, if I may use the term, is 80 per cent.

Substituting in our formulas the values given, we have as conditions

$$\frac{E}{E+v} \times \frac{4}{5} = \frac{3}{5},$$

or,
$$\frac{E}{E+v} = \frac{3}{4} \text{ or } E = 3v,$$

and
$$v = \frac{l}{70} = \frac{10 \times 5280}{70} = 754,$$

whence,
$$E = 2262 \text{ volts},$$

and
$$E + v = 3016 \text{ volts}.$$

Under like conditions, if the distance is only five miles,

$$E_1 = 1131,$$
$$E_1 + v_1 = 1508, \text{ and so on.}$$

We can easily make a general formula. Let $\lambda =$ the commercial efficiency required. Then we have

$$\frac{Ea\beta}{E+v} = \lambda,$$

or,
$$v = \frac{a\beta - \lambda}{\lambda} E.$$

Also,
$$v = .308\, l \sqrt{\frac{b\beta}{K+L}},$$

whence,
$$E = \frac{.308\, l\lambda}{a\beta - \lambda} \sqrt{\frac{b\beta}{K+L}},$$

which gives the e. m. f. at the motor terminals, and from this all other elements can be deduced.

From these formulae we see that, with fixed conditions not only is the number of volts fall of potential dependent on the distance alone, *but with any fixed commercial efficiency the e. m. f. at the*

motor and generator terminals is also dependent simply on the distance.

Again, *the number of volts fall and the motor e. m. f. vary inversely as the square root of the cost of the generating plant.*

Another fact is important. Since the circular mils vary inversely as *Ev, the size, weight, and cost of the wire vary directly as the cost of the generating plant.*

One of the most important applications of the principle of reversibility which I pointed out as characterizing dynamos and motors is its possible use in braking trains. The electromotive force depends upon the strength of the field and the velocity of the armature, and is independent of everything else. It is evident, therefore, that if the strength of the field magnet is increased, the motor electromotive force is also increased; and if the increase of field strength is continued, the initial and counter electromotive forces will become equal, and then the counter or motor electromotive force will predominate. The propelling motor will now become a generator and give current to the line, and its mechanical effects are reversed, so that it brakes the train instead of propelling it, and the current generated by it and the braking power or reversed mechanical effect are now controllable by further increasing or by rediminishing the strength of field.

It will be seen that mechanical energy is received by the reversed motor according to the mass of the train and its velocity. If a train should start on a down grade unprovided with a brake, the energy of falling would tend to increase its speed; but when this method of braking is used, this mechanical energy is transformed in the machine into electrical energy delivered to the line, and augmenting that supplied from the generating stations to the other trains, which may be moving upon up-grades or on levels.

When it is desired to slow down a train on a level grade, the field is increased, as before, until the counter electromotive force predominates over the initial, and the energy stored up in the moving train is exerted to run the machine as a braking dynamo. As the train slows, however, the diminution of speed of the armature will tend to diminish the counter electromotive force, and the increase of field strength must therefore be continued, so as to still maintain the counter electromotive force above the initial and keep the machine running as a generator as long as practicable, when other methods of braking, as, for example, closing the armature circuit on a local regulating resistance or brake circuit, may be used.

I will give an instance to show how effectively this method may be employed, premising that when large masses of iron are used in the field magnets, the strength of the field can be varied within effective limits two or three hundred per cent, and also that a well constructed armature can carry for a short time fifty, seventy-five, or perhaps even one hundred per cent more current than it can stand for any long run. Suppose the armature of a motor to have a resistance of three-tenths of an ohm, with field coils in shunt relation, and provided with suitable means for varying their strength. Suppose the initial electromotive force to be five hundred volts, and forty horse power to be required from the motor when running at its maximum. Allowing for losses in conversion, this forty horse power would be about thirty-two thousand watts. The counter electromotive force would be four hundred and eighty volts, the effective electromotive force twenty volts, and the current sixty-seven ampères. The electrical efficiency of the armature would be ninety-six per cent. Suppose the strength of the field to be increased about four per cent, the speed remaining the same, the motor running on a down grade; the counter electromotive will be increased to five hundred volts, and the motor armature will then be perfectly passive electrically, neither taking from nor giving to the line. Let the field strength be increased again one per cent, and let the increase be continued in the same ratio. The result is shown in the following table:

Total field increase.	Current to line.	Approximate energy required from train, allowing for losses.
5 per cent.	13.3 ampères.	9.5 horse power.
6	29.3	20.9
7	45.3	32.7
8	61.3	44.7
9	77.3	56.9
10	93.3	69.3

From the above it will be seen that by simply increasing the field strength one twenty-fifth part, the machine is converted from a motor driving a train with forty horse power of effective work, to a perfectly passive machine, allowing the train to run absolutely free. Then by increasing the field one one-hundredth part the motor at once exerts a positive braking force, and on an increase of about eight and one-half per cent above its original strength it will give back to the line current equal to that which was originally taken from it, sufficient, evidently, to run some other motor of the system which may at that time require

that amount of current; and by increasing the original field ten per cent the machine acts as a dynamo, requiring more than fifty per cent more energy than is demanded to run it as a motor developing forty horse power.

This method of braking, it will be seen, is under perfect control, and it is the most economical system possible for an electric railway, since whenever a train descends a grade, and whenever a train stops, the energy stored up in the moving train is delivered in the form of electrical energy upon the line.

Consider for a moment what occurs on a steam railway train making frequent stops at short intervals. Suppose it to be ascending a grade, then the engine exerts more than its average amount of power. When it reaches the top and enters upon a down grade, steam is shut off, and when the train begins to run faster than is desired, the brakes are put on, and the energy of the train is then converted into heat on the rims of the wheels and on the brake-shoes. In other words, all the energy in excess of that necessary to run the train on a level which has been required to climb the grade is now thrown away in going down the grade, instead of being utilized, as in this system; and, furthermore, additional steam is actually required to check the tendency to augmented speed. Then when the train approaches a stopping place, or whenever it is necessary to slow the train down quickly, steam has to be employed to actuate the brakes, and all this additional power is simply thrown away. By the electrical method of working, the greater part of this loss may be entirely obviated.

It is true that not all of the energy will be converted into electricity, but a large proportion of it will be.

On a double-track road, with both tracks supplied from the same main circuit, the energy given to one track is also communicated to the other. The up-grades on one track being always balanced by the down-grades on the other track, it is evident that the total up-grade of the whole system is equal to the total down-grade thereof. Therefore, energy being expended on the up-grades, and given out to nearly the same extent on the down-grades, the energy required in the system is that sufficient to move a train upon a level with a slight percentage added; but on a steam railway the energy required is not only that sufficient to run a train on a level, but, in addition, that necessary to raise it from the lower to the higher grades on both tracks, no matter how many of such grades there may be.

Suppose the Third Avenue "L" road of New York were equipped with electric motors, let us consider what the application of this method of braking would mean. There were not long ago, at about six o'clock in the evening, sixty-three trains in operation at one time on about eight miles of double track. The maximum capacity of the engines is about one hundred and eighty horse power, giving an aggregate of 11,340 horses. The work, however, is continually varying, because the trains have to make stations about one-third of a mile apart in eighty seconds, and the average work done is only about seventy-one horses, or 4473 horses total.

Yet the wasteful character of the expenditure is shown by the fact that fifty-nine per cent is expended in overcoming the inertia of the train in getting underway, twenty-four per cent in lifting it on grades, and seventeen per cent only in traction. If the 4473 horse power which represents the average were supplied by electricity in the ordinarily proposed methods, with a recovery of say sixty per cent, then there would be required not less than 7455 horse power at the central stations. By using the system of braking I have described on down grades and in stopping, enough of the energy of the train can be reconverted into electricity to entirely make up all the losses of conversion, transmission and reconversion, so that at the central station only about 4473 horse power would be required, a saving in investment, and coal consumption of $7455 - 4473 = 2982$ horse power.

Instead of the current being all supplied by the main generating station at one or more points, it would be supplied from nearly as many additional moving stations distributed along the whole line, as there are trains slowing down or running on down grades. With any given size of conductor, the loss would be much less, and, with the same losses, the sizes of conductors could be very much reduced.

I have thus shown how, in the application of motors to both stationary and railroad work, the control of the motor electromotive force is the key to the control of the power and speed. I will give one or two more illustrations of the practical character of this theory and how it may be utilized. In our factory one of the methods that we have of testing motors is the following. The power which we have is limited. We sometimes wish to test a number of motors together, and in doing so to develop an amount of power which it is impossible for us to spare from our shafting. Suppose, for example, that we wish to test two 20 horse power and two 7½ horse power motors, an aggregate of about 55 horse power. One of these 7½ horse power motors is

driven as a dynamo. This is electrically connected to the second one, which is driven from the first as a motor. Overhead, we have a line of countershafting, on which are three pulleys. Our two 20 horse power machines are belted up to these pulleys, and likewise the 7½ horse power motor. The like terminals of the large motors are then connected together, and an ampère meter put into one branch of the circuit. One terminal of each field is likewise connected to its proper line, and the other terminals of these fields are brought to the movable levers of a three-part circuit changing switch. One contact is carried to the other line, and between it and the other two is inserted a variable resistance, which, in the middle position of the switch, is short circuited. We have, then, the two large motors connected in an *electro-mechanical couple*, and to the same mechanical shafting is connected a third motor. The dynamo being started, the switch set in the middle position, the motor is speeded up, which sets the countershafting in operation, and drives both the 20 horse power motors as dynamos, each exciting its own field. If the machines are symmetrical, no current whatsoever will pass over the branch connecting the two; they are simply in the position of two dynamos in parallel circuit with each other, with no external circuit and no path over which the current can flow, except that through their field magnets; consequently, very little power, save that of friction, is taken. The switch being moved in one direction, the resistance is thrown into the field of one machine. The electromotive force which it develops at this particular speed is now reduced; it becomes a motor, and current will flow over the connecting mains from the other machine, which is now a dynamo, which current is expressed by the quotient of the difference of the electromotive force of the two machines by the resistance of the two armatures and the connecting mains. By varying this resistance, this current can be made of any value up to the limit. We have here, then, one machine acting as a motor, and driving on to the countershafting with a certain number of horse power, this countershafting driving the other machine as a dynamo with a certain greater amount of horse power, this second machine furnishing the current which operates the first as a motor. The deficit, or loss of efficiency between the two machines, is made up by the third 7½ horse power motor; in other words, one machine is driving the other electrically as a motor, and the motor through the countershafting is driving the first one mechanically as a dynamo, the deficiency being made up

as I have just said. By reversing the switch, the resistance is first cut out of the field, and then thrown into the field of the opposite machine. This machine now becomes a motor, and the other machine becomes a dynamo. This reversal is not instantaneous, because it takes time for the field magnets to charge and discharge. The ampère meter will drop to zero, and will then rise again progressively.

This method of testing can be used for two purposes, one for testing the actual horse power developed and the *couple efficiency*, which can be done by measuring the current, the electromotive force between the machines and the horse power delivered to the shafting by the third motor, and for the other purpose of testing simply the heating capacity of the armature coils with a given number of ampères. For this latter purpose it does not matter practically whether the machines are run at their normal speed and generate their normal electromotive force, or whether some lower electromotive force is used. If a lower electromotive force is present, it simply means that there must be a greater ratio of difference between the field magnet strengths and a larger resistance used with the reversing switch.

This method of testing, where there can be an instantaneous and controllable reversibility of the dynamo and motor by the mere touch of the finger, is probably one of the most beautiful, as it is one of the most useful, applications of this characteristic of machines. By it we can test motors of a capacity of, say, fifty-five horse power, with a belt expenditure of about eight or ten horse power.

A similar method of testing can be used in testing the dynamos employed on alternating circuits. It is now customary in testing large machines, say one thousand lights capacity, to use banks of lamps or artificial resistances to test their capacities. Mr. Hopkinson pointed out, some five or six years ago, that two alternating-current machines could be operated in multiple circuit, but could not be operated in series, and one of the practical things which have been developed is this: that if two alternating machines are run in multiple circuit, before they can be thrown together in safety that they have to be brought into unison. It must be remembered that in an alternating-current machine the variation of electromotive force instead of being two or three, or four or five per cent, as with a constant-current machine, is of the greatest degree. With a one thousand-volt machine, the electromotive force is first as one thousand volts positive and then one thousand volts negative, and this

may occur a hundred times a second. If two machines which are not in unison are thrown together on the same circuit, one is retarded and the other is accelerated, the one acting as a dynamo and the other as a motor, and in the twinkling of an eye they are brought into unison with a report and a shock so sharp that it has for the uninitiated a startling effect, and is, of course, a very severe wrench upon the machines. It is common to excite the field magnets of alternating-current machines by separate exciters. If they run at the same speed, have the same characteristics and have field magnets of the same strength, then when they are in unison both machines will act as dynamos, and neither will take or give current to or from the other. If they are out of unison, then because of the rapidity of the pulsations of these phases and the great change of electromotive forces in the machines they will necessarily come together. One cannot be run as a motor and the other as a dynamo practically by maintaining them out of unison.

Let the two machines be, however, started together with zero fields, and when running at their normal speed let the field magnets be gradually strengthened. The machines will come to unison without trouble. If now, when thus running in unison, the exciting circuit be arranged, as is very easy, so that the field magnets of either can be weakened, then the phase curve of one may be made lower than that of the other by any required degree. The pulsations will be the same in number, they will change in character at the same instant and in the same way, but since there is a difference of electromotive force, the one developing, say, five per cent more than the other, then one will be running as a motor and the other as a dynamo. Both can be driven off the same line of countershafting or engine, and two one thousand-light machines can be tested to their full current-carrying capacity with a very small fractional part of the power which they each separately require, and their dynamo and motor phases can be reversed with the same rapidity and with the same ease and safety as I have described with the constant current machines.

You have been kind enough to express a wish to hear something of the commercial development that has taken place, and I will give you briefly some facts showing how entirely beyond the visionary realm the transmission of power has gone. Some three years ago, the first electric motors which I put into practical use in territory outside of my own jurisdiction were sent to Lawrence, Massachu-

setts, and one of these was used in an isolated plant for operating a cotton elevator in the Pemberton Mills. Since that time the work has gone forward steadily, at first slowly, and of late with a rapidity which has exceeded my most sanguine expectations.

The first companies on whose circuits what are called the constant speed motors were first introduced were the circuits of the Edison Electric Illuminating Companies, and now a very large number of these companies, as well as many others, are coming to realize that one of the most important matters to which they can give their attention is the development of the use of motors for all industrial purposes within the range of the territory covered by their conductors. The result has been that these machines are now being introduced in the United States in the cities of New York, Chicago, Boston, Des Moines, Elgin, Oskaloosa, Pittsburgh, Chester, Williamsport, Lancaster, Shamokin, York, Detroit, Topeka, Hutchinson, New Orleans, Cleveland, Cincinnati, Springfield, New Brunswick, Fall River, New Bedford, Milford, Taunton, Lawrence, Woonsocket, Fort Meyer, Waterbury, Annapolis, St. Louis, Abilene, Pawtucket, Syracuse, and also into Canada, the Argentine Republic, Austria, Germany, Italy, and Japan, and they are being applied to every possible use. In Boston there have been introduced within the past few months nearly sixty of these machines on one circuit, varying from one-half to fifteen horse power in capacity. In New York there are about sixty machines in operation, and the number is now rapidly increasing.

The position I early took in this matter was briefly this: that electricity could fill the field in a far more complete and satisfactory manner than, but in very much the same general way, as the distribution of power from a central station by means of gas, steam, water, or compressed air. The use of any of these elements involves engineering problems. To be successfully solved, not merely as a scientific fact, but in a commercial sense, every part of such system should be in thorough accord with every other part. It is not sufficient that there should be a good dynamo, or a good system of distribution, or a good motor, but that they should be definitely related, the units, the distribution, the area of the distribution, the sizes of the conductors, and the electromotive forces being determined with reference to each other, and to the ultimate demands to be made upon the central station. Nor could any elements of such a system be in doubt. It goes almost without saying that large engines can be operated and large

powers developed under as little general supervision as smaller ones, and under far less supervision than several units of small powers. The cost of the generation of power is much less in large engines, both in the amount of coal and water used and the matter of attendance, and also in the general expense. It follows, then, that if the power of a manufacturing district can be centralized, it can be developed at a much higher efficiency and at a very much lower cost than where it is being generated in a large number of units. If, after such centralization, it can be distributed to a large number of users in the district with only a moderate loss, then supposing only that the same amount of power is sold as is generated in the central station, this plan of generating power would still have the advantage, in point of economy; but when we take into account, as shown by our records, and as is being borne out by practical experience every day, that under the circumstances a central station can take advantage of a low average percentage in use of the capacity of machines, it then becomes apparent that if the system is properly constructed and operated there is not only not a loss, but a great gain in the centralization of steam power; and this will hold true whether dealing with a central station of one hundred or ten thousand horse power, and, if operating under proper electromotive forces, whether the district is a square mile or ten square miles. In fact, electricity is the most convenient, tractable, yet powerful means of carrying and distributing energy or motion from one point to another. As a means of transmission, it has greater advantage over steam, water, gas, or compressed air, in that the system of conductors is far more flexible in its arrangements, and capable of much greater ramifications than any of its competitors. It can be operated under much higher relative pressures or potentials than the other methods of conducting power, and hence it can be distributed with very much smaller conductors and much smaller investments and losses. Of course the truth of this depends upon the efficiency of the different parts of the system.

There are three ways in which power is lost after it is generated in a steam engine and delivered to the dynamo pulleys. The first is in the dynamo. This has now been brought to such a high state of efficiency that there are several good types of machines which have a commercial efficiency as high as ninety per cent. The second loss is that which occurs in the distributing wires or conductors, and this depends upon the electromotive force used, the distance over which the current is distributed, the distribution and arrangement of the

conductors, and the amount of current carried. This loss should not exceed in a general district over ten per cent. The third loss is in the motors, where the energy of the electricity is reconverted into mechanical power. Motors vary in their efficiency. To truly answer the commercial conditions, the current used should be almost directly proportional to the work done. The higher the efficiency of the motor, the more nearly will this law hold. Small machines are not as efficient as large ones, nor is every motor of equal efficiency under all loads; but in large machines the efficiency under full loads is now about ninety-one per cent.

As between two motors of differing efficiency, with that of the lesser efficiency not only would the size of the conductors which would be needed in a particular area to distribute a given amount of mechanical work be much increased, and the area over which any given amount of power could be distributed with a given weight of conductor be very much smaller, but also the capacity of both the dynamos and engines in a central station would have to be very materially increased to get a given output of mechanical work. Increased area, lessened weight of copper, greater recovery of power, and a larger amount of mechanical output, as well as a greater excess capacity of motors, and a less proportional investment in central station appliances and equipments—all these are in favor of the motor having the highest efficiency. The effect upon the lights where they are supplied from the same circuit is also very much less marked with motors of higher than with motors of lower efficiency. In transmitting power over long distances, even in single units, any increase whatsoever in the efficency of the motor or dynamo becomes exceedingly important, because the investments in conductors are very large.

Theoretical conclusions, however, were not of sufficient weight, nor were they generally understood, and one of the greatest difficulties we met with in the introduction of motors was that of determining a method of charging for power, because, on account of the lack of knowledge of the character of the machines and the variable work which they have to do, a contract basis seemed at first inadvisable, and the ordinary current rates for lamps seemed exorbitantly high. Few managers could rid themselves of the notion that, because there was a loss, first in the dynamo, then in the conductors, and finally again in the motors, covering an aggregate of about thirty-five per cent, that it would be impossible to compete with steam when supplied directly. In order to determine these facts, and to prove to

people who were selling power, not only that there was not a loss, but actually an apparent gain in the transmission from a central station; that motors were not to be treated as toys, but as important factors in the industrial arts, and that they would be justified in making a charge for electric power service based upon the sensible method of a contract—records were obtained and calculations made something after the following manner: After several motors had been put into use, we sent out a blank circular requesting, among other things, the number of hours' use which the motors averaged every day, the class of duty, and also the monthly payments, then mostly made on a meter basis. The reports were varied. Some of the records extended over considerable periods of time, and they established the fact that motors, as a rule, do not average over thirty-three per cent of their capacity for the ten hours of a working day. This, in fact, is a large average. This may to a great extent be understood from the following statements: A motor is absolutely automatic. The total current used in machines of high efficiency is almost directly proportional to the work done at any instant. The result is that if the work slacks for a moment, so also does the current, and in nearly the same ratio. Almost all work is spasmodic in character. Motors have to be put in for their maximum capacity, but not one class of work out of a hundred offers continuous duty. Some motors are stopped, and in others which are running the work is constantly varying from the maximum to the minimum. An illustration of this may be cited in the case of elevators. If twenty elevators, each requiring a maximum of five horse power, were driven from the same line of countershafting, they would not require an engine of over forty horse power, because some would be going up, some going down, others standing still, and in not two cases out of the twenty would simultaneous trips be made, while in not one trip in five hundred would an elevator be hoisting its maximum load from the basement to the loft. Comparison also may be made with existing incandescent light plants. Practical experience shows that not over fifty-five or sixty per cent of the total number of lights connected on a station are used at any one time, although it is possible to use them all. But incandescent lamps when they are in use take their full amount of current. Not so with motors. A certain percentage of the motors, just as with the lights, would not be in use at all, and in most of those in use the current would be continually varying, just as if the lights of an incandescent light station were being

turned up and down from one to sixteen candle power, as well as many of them being turned out. The recovery in an ordinary district with eighty-eight to ninety per cent of the power delivered to the dynamo pulleys converted into electricity on the line, and ten per cent loss in distribution, is about sixty-five per cent. This sixty-five per cent, however, where the work is distributed, is only thirty-three per cent of the capacity of the motors for which power can be contracted. In other words, for every one hundred horse power in a central station, sixty-five horse power at any one instant can be delivered under an ordinary distribution, and this sixty-five per cent is only one-third of the power which can be contracted for, provided there are a large number of motors in use. Of course, where only one motor can be used, then sixty-five horse power only would be obtained, but the object of a central station is to take advantage of the intermittent character of the work, and that it can be done is shown by the records which we have of a large number of motors in use.

The future, then, of motors in connection with central stations is assured, but the application of motors to stationary work, or more properly in combination with centres of supply such as the ordinary stations for electric lighting and power, is but one field, although a large one. There are many special fields of work, each of which demands large capital, and offers a wide range of application. Among these may be mentioned the application of the transmission of power to mining works. At present, in single plants, both in the mining of the common and of the precious metals, immense sums are invested in elaborate systems for the transmission of power by compressed air, single plants sometimes costing as much as a half a million dollars. Such a system of transmission must necessarily be costly. Not one case exists in which electricity could not be better used and with a very much reduced investment.

The transmission of power in single units for a variety of purposes too numerous to mention, such as, for instance, the operation of the transfer tables of the C., B., and Q. Railroad at Aurora, and the operation of overhead cranes, is itself a field requiring a great deal of thought. Some idea of the progress made may be gathered from the fact that we have now about twenty-five or thirty different types and classes of machines, and I know that the near future will require fifty or seventy-five.

Again, the substitution of motors for horses in street car work, using in some cases the conduit, in others the overhead wire, and

others the storage battery, is now rapidly coming into favor. On the two latter classes of work we are now actively engaged, and are just at present much interested in the most extensive electric railway system which has ever been contracted for, that of Richmond, which comprises forty cars and eleven miles of track. The great margin between steam and horse power gives ample room for increased efficiency and lessened cost of operation, especially where a number of cars are in operation, because here, as in regular central station work, the apparent output of power will be greater than the actual power of the central station, and, unlike horses, the motors do not require to be fed for twenty-four hours in the day independent of whether they are being used or not.

In one sense, that of size, the most important immediate experiment in which I am engaged is the development of motors for application to the movement of heavy trains on the elevated railroad. I was engaged last year for a considerable period in carrying on experiments on one of the branches of the elevated railroad, during the progress of which one of the standard elevated railroad cars, on a heavy grade and with a current of about six hundred volts potential, was handled under all speeds up to twenty-one miles an hour entirely by the motors, and without the use of hand-brakes, the practice of the recovery of the energy of the car, of which I have already spoken, being there very thoroughly developed. We have now stopped this experiment and have under way the largest apparatus of the kind ever undertaken. This consists of a motor car of special construction, which is designed partially for passengers, and is intended to haul itself and five or six other cars; in other words, a hundred and forty ton train, and this at speeds as high as twenty-eight miles an hour. The middle portion of this car is to be used for passengers, but each end is reserved for the engineer and for duplicate controlling apparatus. Under each end of the car is a heavy iron truck fitted with two pairs of forty-two inch Krupp wheels and five-inch Midvale steel axles. On each axle is to be placed a duplex motor, the normal capacity of which is seventy-five horse power, but which can be worked up to a capacity considerably higher than this. Each motor is centered on the driving axle and drives from each end of the armature. Each motor weighs four tons. The armatures, of which there will be eight altogether, are about eighteen inches long and seventeen inches in diameter. Each of the eight field magnets with its wire will weigh at least a ton. The total weight of the car with passengers will

be about thirty-two tons, but it is distributed over the entire distance between two columns. With a tangential strain on each armature of only about twelve hundred pounds, there will be a draw-bar strain of nearly 13,000 pounds; and this is not by any means the full capacity of the motors. The total power of the motors on this car will be double that of the heaviest locomotive on the road, and the traction coefficient more than twice as much. It will be some months before this is ready, because the work is being elaborated in great detail.

One of the most important applications to which I may call the attention of the gentlemen present is that of the use of electric motors on board ship. The uses to which motors can be applied on a man-of-war are numerous. It will probably be argued by many, when the proposals are made to carry on certain operations by means of electricity, that there is some doubt as to their practicability in so complex an organization and one subject to so many peculiar conditions not met with elsewhere as is a man-of-war. Similar objections were made a few years ago when it was suggested that the incandescent electric light ought to be introduced in the place of the then existing system of lighting. In 1881 I made some efforts to introduce the incandescent electric light on board our ships, and afterwards in 1882 I attended an exhibition at the Crystal Palace, Sydenham, England, and being required to report upon the progress of electric lighting, made as strong a report as I could in favor of this innovation. Whether this report had any weight or not, of course I do not know, but it seems that most of the objections which were raised against electric light proved unfounded, for various systems are being introduced and are giving satisfaction, and so thoroughly satisfied are officers that the proper method of lighting ships is by electricity that few of them would to-day think, for one moment, of seeing the old days return with their antiquated, unpleasant and unhealthy methods of illumination. So may we look upon the application of electricity as a motive power to a great variety of uses on board ship, and that with far more certainty of operation, more ease in manipulation, than in many machines now used. Few people not acquainted with the actual conditions met with on board ship realize the number of small engines in use and the variety of purposes to which they are applied. Steam has superseded hand steering apparatus; steam ventilation takes the place of wind-chutes; blowers, exhaust fans, and pumping machinery are driven by steam; ashes are hoisted by its agency. Shell hoisting

and gun training, which is now performed sometimes by hand and again by pneumatic, hydraulic, or steam apparatus, will certainly, sooner or later, be better done by means of electro-motors. In fact we have been asked already by the Department to submit designs for operating the new 8-inch rifle gun for the Chicago, and are now working on these; the motor will be carried beneath the gun inside the carriage and the training will be under perfect control. Of course I do not say that the first experiment of this kind will be entirely successful, or that it will be devoid of objections. A perfect apparatus in this, as in any other line, must be developed by the process of evolution. It is not always possible to foretell every condition which will be met; but failures are simply the keys to success. The hoisting of shell and other ammunition, now done laboriously and uncertainly by hand, can be better done by positive acting electro-motors which will be under perfect control. Centrifugal pumps, with their rotary movement and high speed, and likewise fans and exhausters, both for ventilation and for forced draft in the furnaces, will be run by motors. It may be urged that there is a liability of accidents occurring with apparatus of this nature. In answer we can say that duplicate parts are easily carried and injured portions quickly replaced—if anything, more quickly than in any steam apparatus. One of the great advantages of the use of electricity for these purposes will be the avoidance of a great deal of heat now caused by carrying steam pipes all over the ships. Steam steering gear is now operated in a clumsy, uncertain method from the forward and after pilot houses by long lines of countershafting and gearing which, because of the general structure of the ship, cannot be other than objectionable. The electro-motor will replace this gearing in the near future, and so it will go on and eventually replace the steam apparatus itself. I do not think I can be rightly accused of speaking merely as an enthusiast, but may fairly claim to understand some of the conditions which obtain in ship life, and I feel warranted in expressing my own confidence that the future will solve every difficulty which the application of electricity to classes of motive power I have mentioned on board ship may demand. One of the great advantages in the use of electricity on board ship is the ease with which the conductors may be handled and run as compared with steam pipes, and also the facility with which they can be replaced in case of accident. The generating apparatus can be placed well out of the range of shot and shell, and easily protected. Another field for electric motors on

board ship is in making repairs. To-day, if a drill is to be operated, a new bolt hole made, or any other work requiring tools of this character, they must be operated by a slow, tedious handgear; whereas a portable motor, with its flexible shaft and brace, can be introduced in the most out of the way part of boilers and engines, and work there performed which, were it done in the ordinary method, would require extensive preparations involving, possibly, the removal of heavy parts of machinery. Torpedoes can be operated as well as controlled by electricity. Diving operations and repairs to the ship's skin under water and in dock, repairs to armor, turrets, and to gun carriages can all be facilitated by the use of electric motors.

The methods of making these various applications of electric power may well receive the careful thought and criticism of all officers who desire the best good of the service, and I have no doubt but that many most valuable suggestions will in the future come from those who to-day look with conservative doubt upon the practicability of these proposals.

DISCUSSION.

THE CHAIRMAN.—*Gentlemen:*—There is no practical application of electricity that is now attracting more attention or is of greater importance than the transmission of power by electricity. The telephone may be greatly improved, but it has taken its place as a successful invention and an indispensable instrument in conducting the ordinary affairs of life. It is not improbable that in a few years the electric motor will be made more useful than the telephone.

The science of electricity is so far advanced that no ignorant man will by accident hit upon a successful motor. Such a motor must be constructed in strict accordance with scientific principles. To be successful in these days of close competition it must be more than almost correct—it must be exactly right. It will be the result of the thoughtful work and experiment of an ingenious man well trained in modern science.

We are very fortunate in having had the opportunity to listen to one so thoroughly competent, so ingenious, so enthusiastic, and so successful as the lecturer of this evening.

The Naval Academy is to be congratulated that one of its graduates is in a position to return and, in this building, where he received his first theoretical and practical training in physical science, speak with authority as one of the foremost inventors and investigators in this branch of electrical science.

The subject is now before the Institute for general discussion. Mr. Sprague will, I doubt not, be happy to answer any questions that members of the Institute may wish to ask.

After some discussion of the feasibility of transmitting power over great distances, and of methods for testing the efficiency of motors, a vote of thanks, on the motion of Commander P. F. Harrington, was extended to Mr. Sprague for his valuable and instructive paper. The meeting then adjourned.

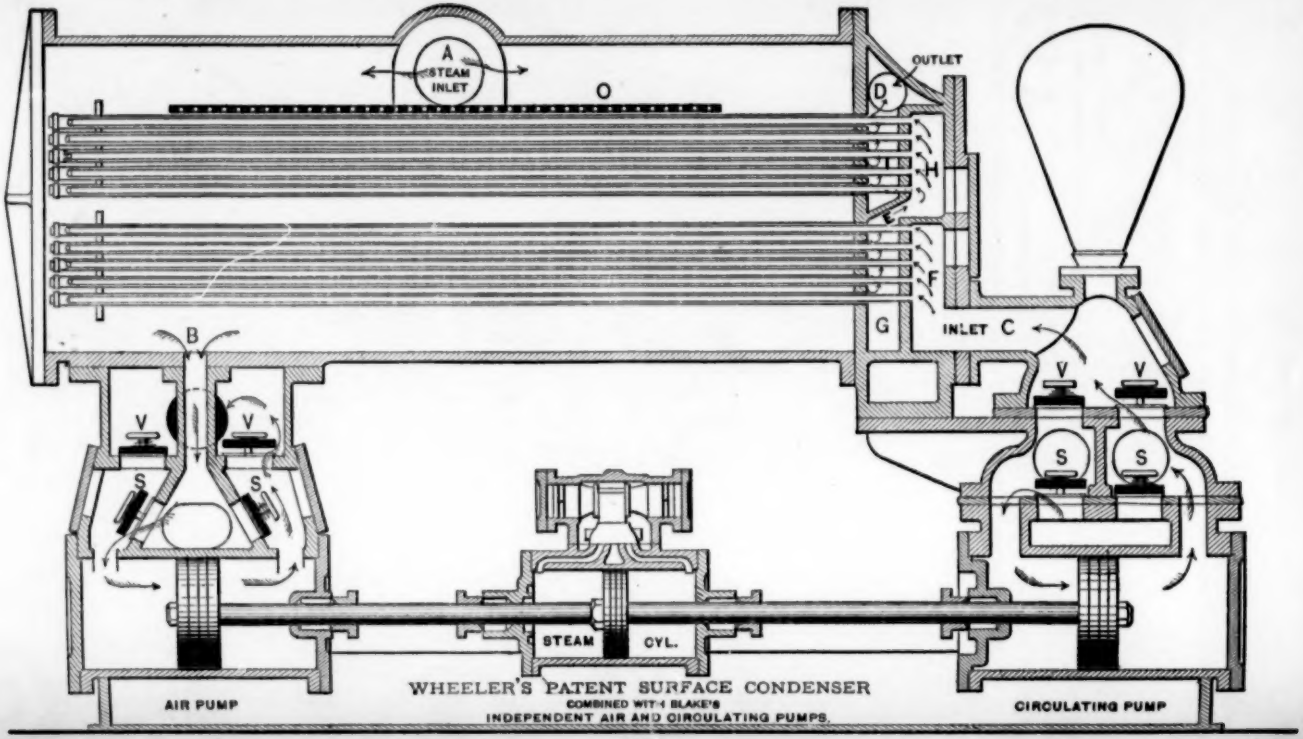

A
STEAM
INLET
O
OUTLET
D
H
F
G
INLET C
B
V
V
V
V
S
S
S
S
STEAM
CYL.
WHEELER'S PATENT SURFACE CONDENSER
COMBINED WITH BLAKE'S
INDEPENDENT AIR AND CIRCULATING PUMPS.
AIR PUMP
CIRCULATING PUMP

FIG. 1.

PROFESSIONAL NOTES.

[COPYRIGHTED.]

THE WHEELER SURFACE CONDENSER.

By W. F. Worthington, P. A. Engineer, U. S. N.

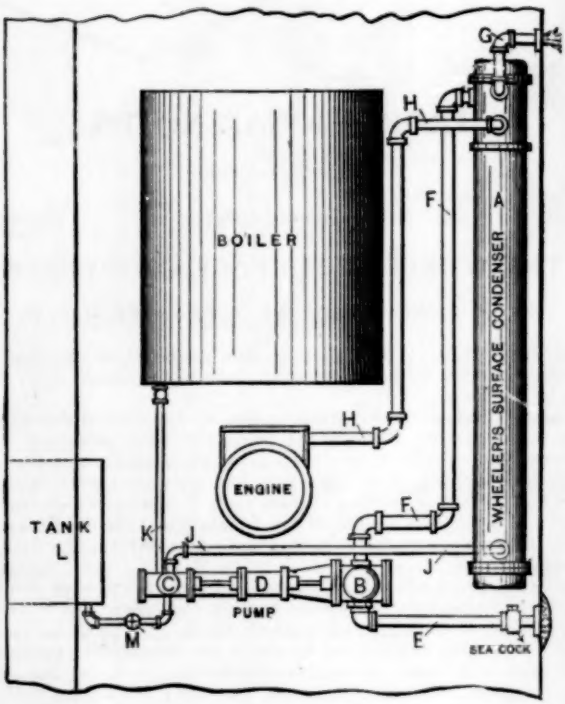
This condenser (Fig. 1) is similar to that patented by Mr. Loftus Perkins and described by him in a paper* read before the Institute of Mechanical Engineers in England.

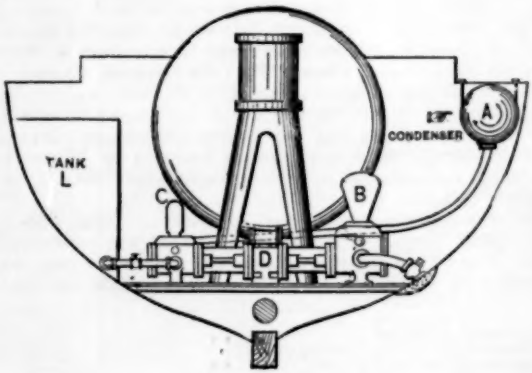
The principal feature is the arrangement of one tube within the other, the circulating water passing through the inner tube and returning through the space between the tubes. It is readily seen, by inspection of the figure, that with this system the weight of the tubes and contained water will be slightly greater per square foot of cooling surface than it is with the ordinary arrangement of the tubes, and the weight of the remainder of the condenser about the same. The advantages to be expected are: first, increased efficiency of the tube surface; second, decreased work to be done by the circulating pump. With regard to the first advantage, extensive experiments were made by Joule† with apparatus similar in arrangement to this condenser, but differing in the unimportant detail that the steam passed inside and the water outside of the condensing tube. The experiment in which the condensing surface was most efficient showed that nearly 32 pounds of dry steam, entering the condenser at 30 pounds pressure, could be condensed per hour per square foot of surface with the injection at 44° F., discharge 90° F., hot well 122° F., and a vacuum of 26 inches maintained. This result is much in excess of those attained with the ordinary form of condenser, in which the tube surface is calculated to condense about 9 pounds of steam per square foot per hour,‡ and 13 pounds per square foot per hour is considered very fair work§ when the injection is 60° F. and feed 120° F. Joule's experiment referred to was made with a clean copper tube, but further experiments showed that the material, whether copper, iron, or lead, and the thickness within reasonable limits, made no practical difference. The principal difficulty in the conduction of heat arose from a film of water adhering to the tube surface, and any means adopted to prevent this largely increased the efficiency. The arrangement adopted by Wheeler is well calculated to compel a circulation at the tube surface and may fairly be expected to give excellent results.

With regard to the second advantage. Joule found that with equal weights of circulating water the weight of water condensed was increased by diminishing the space between the inner and outer tube, and in one case, when the space was decreased from 0.325 inch to 0.06 inch, the weight of condensed steam

*Engineer, London, June 8, 1877.
†Scientific Papers of J. P. Joule, London, 1884.
‡Die Schiffsmaschine, Busley, Kiel, 1883.
§Manual of Marine Engineering, Seaton, London, 1883.

FIG. 2.


BOILER
WHEELER'S SURFACE CONDENSER
ENGINE
TANK
L
PUMP
SEA COCK
A
B
C
D
E
F
G
H
J
K
M


CONDENSER
TANK
L
A
B
C
D

was nearly doubled, while the weight of circulating water remained the same. The increase of the hydraulic head necessary to force the water through the tubes in the second case was very little, so that the saving in work done by the circulating pump with Wheeler's arrangement would probably be considerable. Furthermore, Joule found that by placing between the inner and outer tube, wire coiled in form of a helix to give a rotary motion to the water, the efficiency of the condensing surface was still further increased without materially affecting the hydraulic head required to force the water through the tubes, a fact which goes to show that a large part of the work done by the circulating pump with the ordinary form of condenser is wasted.

Experiments with a small condenser of the Wheeler type* with 4.27 square feet of tube surface showed nearly 102 pounds of steam condensed per square foot per hour, the injection being 56½° F., discharge 98° F., hot well 138° F., vacuum 24½ inches. This is a much better result than any obtained by Joule with the apparatus before mentioned. The difference may be partly accounted for if the steam was very wet, while that in Joule's experiments was known to be quite dry. Also the ratio of length to diameter of the tubes may have been better than in Joule's apparatus, it being well known that the evaporative efficiency of locomotive boilers is considerably affected by slight changes in these proportions.

One of the advantages of the Wheeler condenser is the ease with which the tubes may be removed for cleaning or renewal. An eminent authority† says that facility for cleaning the tubes is the principal point to be considered in designing a condenser.

Another advantage is that the tubes being screwed into the tube sheets and free on one end, there is no trouble from "crawling," and no packing to get leaky if the condenser is unused for a long period, as often occurs with naval vessels, or to be injured by accidental overheating of the condenser or by boiling to clean the tubes.

The body of the condenser shown in the figure for use on land is made of cast iron, but for use on shipboard these condensers are also made of steel, wought iron, or rolled brass plates. The cylindrical form of cross section allows the weight to be reduced to a minimum.

Fig. 2 shows a plan and elevation of the "light-weight" condenser adapted for yachts, launches, etc.

COLLISION, OR GROUNDING MAT.

By Commander G. King Hall, R. N.

[*Reprinted from Journal of the Royal United Service Institution.*]

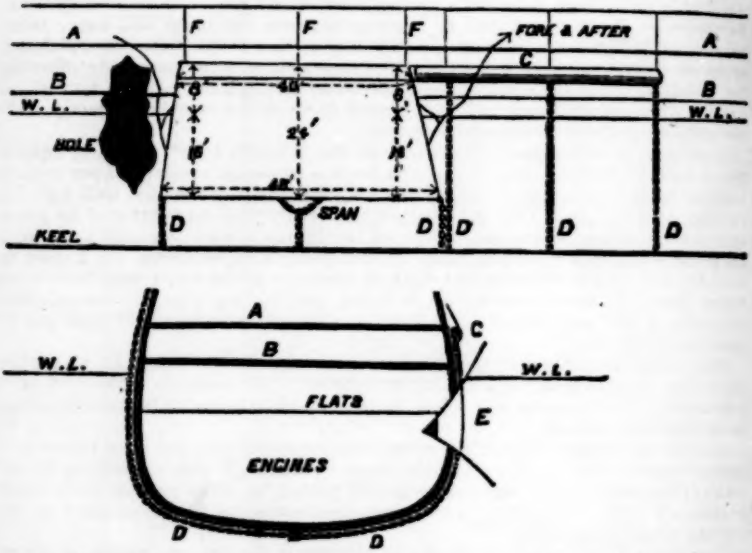
As an officer who has served some years as First Lieutenant and Commander, I am convinced that the present collision mat, 12′ by 12′, is of little practical use, and those who know the difficulty of placing these mats and the time required—not to getting it over for drill purposes, but of accurately placing it—will agree with me that if a ship be rammed, and a serious hole made in her, by the time the mat was placed she would be full of water.

I would propose that mats of double No. I canvas should be, when at sea (if considered advisable, in harbor), kept permanently rolled and stopped up on the outside of ship ready for immediate use.

* American Machinist, May 15, 1886.
† Modern Marine Engineering, Burgh, London, 1867.

SHANNON.

(Abreast engine room.)



A Upper Deck. *C* Mat rolled up. *E* Ram of Shannon.
B Main Deck. *D D* Bottom chains. *F F* Tricing lines.

Scale $\frac{1}{32}$" to a foot.

DIMENSIONS OF MAT.

Head, 40 feet long, and has a wire jackstay secured to bolts in ship's side, about 8 feet above water line.

Depth of Mat, about 24 feet, giving about 16 feet under water, the leach having a short fore and after in it, and end kept out when mat is rolled up, ready for immediate use.

Foot, 46 feet (so that the mats should overlap if by any chance the ship was rammed exactly between two mats); and to the foot are attached two iron round bars, 2 inches in diameter (each weighing about 230 pounds) and 23 feet long.

Bottom chains, going from each end of mat and one from the centre, connected by wire or chain span to the two inner ends of bars, consequently each mat would have three bottom lines.

Brails or tricing lines for tricing up foot when required.

In most of our large ships, four of these mats a side would be sufficient (in some of our smaller ironclads, such as the Shannon, three would be ample); four of these mats would cover a space of 160 feet, where the large compartments of ship are, as both forward and aft ships are so much protected by cellular compartments and also by the "run" of ship.

These mats should be always kept on at sea, especially when expecting an engagement; and if in an action the ship were rammed, or a hole made by a Whitehead torpedo, all that would be required would be to cut the straps (or,

if fitted with tumblers, slip the foot), and the mat would then fall into its place, and steady taut the bottom lines; this could be done in two minutes; no bother in the middle of an action about whips, bottom lines, fore and afters, all to be bent on and perhaps foul, in the excitement of moment and difficulty of placing mat under fire.

If ship grounded and a large hole were made more than 16 feet under water, the head of mat can be at once cleared away and mat lowered and hauled over hole.

N. B.—These dimensions are only approximate, and might, on trial, require some slight modifications.

I believe if Vanguard had possessed these mats she would have been saved from sinking.

[COPYRIGHTED.]

REPORT ON THE PERMISSIBLE LIMITS OF ELECTRICAL RESISTANCE OF SERVICE FUZES AND DETONATORS.

TORPEDO STATION, NEWPORT, R. I.,
March 5, 1887.

Sir:—In fixing the limits of electrical resistance for fuze bridges, the service for which they are intended and the firing apparatus to be used with them must be taken into consideration.

The ordinary uses to which electrical fuzes, detonators and cannon primers are put in the service at the present time, are the firing of a single torpedo from a boat, one to four torpedoes from a ship or a broadside battery. Ten may be considered as the maximum number of guns in the broadside of any ship in our service, and the introduction of high-powered guns will probably decrease this number.

The firing apparatus issued to the service are the Farmer's dynamo machines, pattern A and C, and the ship's and boat's firing batteries of six and four M. C. L. cells respectively.

As some vessels are furnished with a boat's outfit only, the A machine and ship's firing battery are not always found on board. The boat's battery is more especially designed to fire a single torpedo from a boat, and as it polarizes rapidly on being used it is not suitable for experimental purposes. It was therefore decided that a fuze bridge of such resistance that ten of them arranged in series might be rapidly and quickly fired by the C machine would best answer the requirements of the service. On this basis the experiments were conducted.

Farmer's C machine having an average electro-motive force of eight volts and an internal resistance of four ohms, has generally been considered as capable of firing from eight to ten fuzes of standard resistance (.62 ohm to .68 ohm, both inclusive) arranged in series, or a single fuze through 1500 feet of Siemens cable such as now used in the service. Using the standard bridge of iridin-platinum wire (90 per cent platinum, 10 per cent iridium) $\frac{3}{16}$ inch long and .002 inch diameter, a current of .6 ampere, which gives a hot resistance of 1.15 ohms to bridge, is necessary to instantly fire gun-cotton, which is used as priming. Neglecting the resistance of leading wires, the C machine is found theoretically capable of firing eight standard fuzes arranged in series. It may be stated that a less current, as, for instance, .5 ampere, is sufficient to fire gun-cotton, but requires a sensible time.

During the experiments it was found that the C machine would practically fire ten fuzes of standard resistance arranged in series, at apparently the same instant. In twelve experiments of this nature, whether the bridges were made up into igniters or simply primed with gun-cotton, there were no failures. When a bridge of .59 ohm resistance or less was introduced into the series

therewere frequent failures, though as a rule when the resistance did not vary much from the standard all the bridges fired. The same may be said of bridges having a resistance greater than standard.

We have not been able to explain the cause of failure in any special case, but a general explanation may be given as follows. In the manufacture of bridges of any standard resistance, variations in resistance may be due to—

1st. Errors in measurement of length of bridge.

2d. Difference in amount of solder used to fastened ends of bridge.

3d. Solder or foreign material adhering to the bridge at the middle or near the ends.

4th. Errors in measurement of bridge resistance due to differences in temperature and humidity of atmosphere.

These errors are to a certain extent unavoidable, but are reduced to a minimum when an experienced workman is employed in the manufacture of the fuzes. It will be seen from the above that a bridge of a certain length may have the same resistance as a longer one having a greater amount of solder at its ends, or solder or foreign material at its middle or near the ends. Also that a bridge having a certain resistance at the time of measurement may have greater or less resistance when required for firing. Bridges having the same resistance but differing in accuracy of construction may, therefore, require different conditions for firing, and bridges of exactly the same construction, measured at different times, may have different resistances. Moreover, in any experiments where a dynamo machine is used, differences in electro-motive force must occur, owing to the variations in turning the crank. Like variations in electro-motive force will occur in the use of a battery which is not constant.

Far better results were obtained when the bridges were simply primed than when made up into igniters. This is explained as follows: When igniters are used, the bridges which are first raised to the required temperature are broken by the explosion of the igniters, thus preventing the others from firing through delayed action. When simply primed with gun-cotton the bridges are seldom burned off, and a continuous turning of the crank of the machine is only necessary to fire all.

As a result of our experiments we are of the opinion that bridges of the wire now in use having an electrical resistance of not more than .70 ohm nor less than .60 ohm are best adapted to the requirements of the service. A somewhat smaller limit should be adopted as an element of safety, because errors are likely to occur in the measurement of resistance from the causes heretofore stated, and because certainty of action is the most important consideration in torpedo practice. The present standard bridge appears to answer all the requirements, and, if the fuzes be properly made by an experienced workman, little or no waste will result from its adoption.

To conclude, we are of the opinion that the present standard bridge, having an electrical resistance of .62 to .68 ohm, both inclusive, is the best, both theoretically and practically, and do therefore recommend that its use in the service be continued.

LIEUTENANT J. A. SHEARMAN, U. S. N.
ENSIGN G. W. DENFELD, U. S. N., *Recorder.*

COMMANDER C. F. GOODRICH, U. S. N.,
Inspector in Charge.

The following is a list of the experiments upon which the above report is based. In each case ten igniters or bridges were connected in series and joined to the C machine by short leading wires.

The tables are arranged in five columns:

The 1st showing the experiment number.

2d, the resistance of the bridge.

3d, the number of igniters or bridges used of resistance shown in the 2d column.

4th, the place of each bridge in the circuit numbered from the positive wire.

5th, the results.

Experiment No.	Resistance.	No. in Series. Igniters.	No. in Series. Bridges.	Place in Circuit.		Results.
1	.62	1		10		Fired.
	.64	5		1, 2, 3, 4, 5		"
	.65	1		9		"
	.66	2		6, 7		"
	.68	1		8		"
2	.62		2	9, 10		"
	.63		1	4		"
	.64		1	5		"
	.65		2	1, 3		"
	.66		2	2, 6		"
	.67		1	7		"
	.68		1	8		"
3	.62		1	6		"
	.63		2	1, 5		
	.64		1	9		
	.65		2	2, 8		
	.66		1	7		
	.67		2	3, 4		
	.68		1	10		
4	.62		2	2, 4		Fired.
	.64		2	1, 5		"
	.65		3	6, 9, 10		"
	.67		2	3, 8		"
	.68		1	7		"
5	.62		2	1, 2	9, 10	"
	.63		1	3	8	"
	.64		1	4	7	"
	.65		2	5, 6	5, 6	"
	.66		1	7	4	"
	.67		2	8, 9	2, 3	"
	.68		1	10	1	"
6	.62		2	1, 2	9, 10	"
	.63		1	3	8	"
	.64		1	4	7	"
	.65		2	5, 6	5, 6	"
	.66		1	7	4	"
	.67		2	8, 9	2, 3	"
	.68		1	10	1	"
7	.62		4	2, 7, 8, 10	1, 3, 4, 9	"
	.63		2	4, 6	4, 5	"
	.65		1	5	6	"
	.66		1	9	2	"
	.67		2	1, 3	8, 10	"

Experiment No.	Resistance.	No. in Series. Igniters.	No. in Series. Bridges.	Place in Circuit.		Results.
8	.62		2	6, 8	3, 5	Fired.
	.64		1	1	10	"
	.65		3	4, 5, 10	1, 6, 7	"
	.66		2	3, 9	2, 8	"
	.67		2	2, 7	4, 9	"
9	.63		2	3, 10	1, 8	"
	.64		3	4, 7, 9	2, 4, 7	"
	.66		1	6	5	"
	.67		3	1, 5, 8	3, 6, 10	"
	.68		1	2	9	"
10	.62		9	1, 2, 3, 4, 6 / 7, 8, 9, 10		"
	.63		1	5		"
11	.64		2	1, 2	9, 10	"
	.65		4	7, 8, 9, 10	1, 2, 3, 4	"
	.66		4	3, 4, 5, 6	5, 6, 7, 8	"
12	.67		5	1, 4, 5, 7, 9		"
	.68		5	2, 3, 6, 8, 10		"
13	.61	1		10		"
	.63	1		1		"
	.64	3		2, 3, 4		"
	.65	5		5, 6, 7, 8, 9		"
14	.60	1		1		"
	.63	1		2		"
	.64	3		3, 4, 5		"
	.65	5		6, 7, 8, 9, 10		"
15	.60	1		1		"
	.63	1		2		"
	.64	3		3, 4, 5		"
	.65	5		6, 7, 8, 9, 10		"
16	.59	1		1		Failed. Afterwards was fired by itself.
	.63	1		2		Fired.
	.64	3		3, 4, 5		"
	.65	5		6, 7, 8, 9, 10		"
17	.57	1		1		"
	.63	1		2		Failed. Afterwards was fired by itself.
	.64	3		3, 4, 5		Fired.
	.65	5		6, 7, 8, 9, 10		"
18	.39	1		1		"

Experiment No.	Resistance.	No. in Series. Igniters.	No. in Series. Bridges.	Place in Circuit.	Results.
18	.62	2		2, 3	Fired.
	.63	5		4, 5, 6, 7, 8	"
	.64	2		9, 10	"
19	.27	1		10	Failed. Afterwards was fired by itself.
	.63	1		1	Fired.
	.64	3		2, 3, 4	"
	.65	5		5, 6, 7, 8, 9	"
20	.64	2		1, 2	
	.65	5		3, 4, 5, 6, 7	
	.66	2		8, 9	
	.77	1		10	
21	.63	1		1	Fired.
	.64	3		2, 3, 4	"
	.65	2		5, 6	"
	.66	3		7, 8, 9	No. 9 failed. Afterwards fired singly.
	.77	1		10	Fired.
22	.62		2	6, 8 | 3, 5	"
	.65		3	4, 5, 10 | 1, 6, 7	"
	.66		2	3, 9 | 2, 8	"
	.67		2	2, 7 | 4, 9	"
	.77		1	1 | 10	"
23	.63	1		2	"
	.64	3		3, 4, 5	"
	.65	5		6, 7, 8, 9, 10	"
	.79	1		1	"
24	.61		1	10	"
	.62		1	9	"
	.63		1	8	"
	.64		1	6	"
	.65		1	3	"
	.66		2	1, 4	"
	.67		1	2	"
	.68		1	5	"
	.69		1	7	"
25	.60		1	8	"
	.61		1	7	"
	.62		1	6	"
	.63		1	10	"
	.64		1	5	"
	.66		1	9	"
	.67		1	3	"
	.68		1	1	"

Experiment No.	Resistance.	No. in Series.		Place in Circuit.	Results.
		Igniters.	Bridges.		
25	.69		1	4	Fired.
	.70		1	2	"
26	.59		1	2	"
	.60		1	3	"
	.61		1	5	"
	.62		1	4	"
	.63		1	10	"
	.67		1	1	"
	.68		1	6	"
	.69		1	7	"
	.70		1	8	"
	.71		1	9	"
27	.59		1	8	"
	.60		1	9	"
	.61		1	6	"
	.62		1	7	"
	.63		1	1	"
	.67		1	10	"
	.68		1	2	"
	.69		1	3	"
	.70		1	4	"
	.71		1	5	"
28	.61	3		1, 2, 3	"
	.62	7		4, 5, 6, 7, 8, 9, 10	"
29	.57		1	5	"
	.62		2	9, 10	"
	.63		1	4	"
	.65		1	3	"
	.66		1	2	"
	.67		1	7	"
	.68		1	8	"
	.70		1	6	"
	.80		1	1	"
30	.50		1	1	"
	.61		1	2	"
	.62		1	3	"
	.63		1	4	"
	.65		1	5	"
	.66		2	6, 7	"
	.68		1	8	"
	.69		1	9	"
	.70		1	10	"
31	.50		1	1	"

Experiment No.	Resistance.	No. in Series. Igniters.	No. in Series. Bridges.	Place in Circuit.	Results.
31	.61		1	2	Fired.
	.62		1	3	"
	.63		1	4	"
	.65		1	5	"
	.66		1	6	"
	.67		1	7	"
	.68		1	8	"
	.69		1	9	"
	.80		1	10	"
32	.41		1	1	No. 1 failed to fire, but fired singly.
	.61		1	2	Fired.
	.62		1	3	"
	.63		1	4	"
	.65		1	5	"
	.66		1	6	"
	.67		1	7	"
	.68		1	8	"
	.69		1	9	"
	.94		1	10	"
33	.57		1	5	"
	.61		1	2	"
	.62		1	10	"
	.63		1	4	"
	.65		1	3	"
	.67		1	7	"
	.68		1	8	"
	.69		1	9	No. 8 failed. Afterwards fired, connected up in same series by turning
	.70		1	6	crank of machine rapidly.
	.80		1	1	
34	.64	2		1, 2	Fired.
	.66	1		3	"
	.68	1		4	"
	.69	4		5, 6, 7, 8	"
	.70	1		9	"
	.71	1		10	"
35	.50	1		1	"
	.53	2		2, 3	"
	.55	1		4	"
	.56	1		5	"
	.59	1		6	"
	.62	3		7, 8, 9	"
	.64	1		10	"
36	.55		5	1, 2, 3, 4, 5	Fired—also when reversed.
	.75		3	6, 7, 8	

Experiment No.	Resistance.	No. in Series. Igniters.	No. in Series. Bridges.	Place in Circuit.	Results.
36	.76		2	9, 10	
37	.55		1	1	Fired—also when reversed.
	.56		1	2	
	.57		1	3	
	.58		1	4	
	.59		1	5	
	.71		1	6	
	.72		1	7	
	.73		1	8	
	.74		1	9	
	.75		1	10	
38	.55		1	3	Fired—also when reversed.
	.56		1	2	
	.57		1	10	
	.58		1	7	
	.61		1	1	
	.69		1	5	
	.70		1	8	
	.72		1	4	
	.74		1	6	
	.75		1	2	
39	.57		1	1 | 10	Fired.
	.58		1	2 | 9	"
	.59		1	3 | 8	"
	.60		2	4, 5 | 6, 7	"
	.61		5	6, 7, 8, 9, 10 | 1, 2, 3, 4, 5	"
40	.74		3	1, 2, 3	Fired—also when reversed.
	.75		3	4, 5, 6	
	.76		4	7, 8, 9, 10	

[COPYRIGHTED.]

PNEUMATIC WATER ELEVATING APPARATUS FOR SUPPLYING SHIPS WITH WATER.

(Invented by ARMISTEAD RUST, Naval Cadet, U. S. N.)

The apparatus consists of a series of tanks in the after hold for containing hot and cold fresh water and the waste water from the bath-tubs and basins of a ship. After a tank is filled with water it is put in connection with a receiver filled with air of sufficient pressure to cause the water to flow up to the basins, or overboard when the proper cocks are opened. The air is compressed by a

pump worked by an eccentric on the main engine shaft, or preferably by a separate engine.

The water in the hot-water tank is heated by a few turns of a steam pipe. It is proposed to use the waste water in case of fire by shutting the outboard connection and attaching a hose to a nozzle provided. Suitable gauges and safety valves are fitted to the tanks. W. F. W.

THE TACTICS OF INFANTRY IN BATTLE.

By Colonel Sir Lumley Graham.

[*Reviewed by Lieut. D. H. Mahan, U. S. N.*]

This interesting pamphlet, reprinted at the U. S. Artillery School, Fortress Monroe, contains a great deal of valuable information. It is well known that neither our Army nor Navy possesses any work on modern tactics. Regiments and brigades are still drilled according to Upton. The deployments and skirmishings as taught are much behind the present system of foreign tactics, and it is necessary that some step should be taken to remedy this state of affairs, to so change our tactics as to make them in some manner similar to those adopted by the military nations, France, Germany, and Austria.

Let us look at some of the general principles adopted by these three nations and see if they will not give food for thought to many of us.

"1. The relative value of the firearms (cannon and musket) and of the side arms (sword and bayonet) has been much affected by modern technical improvements. The firearm is now undoubted mistress of the battle-field, where everything is subordinate to it.

2. The formation of infantry for battle must be such as to favor to the utmost the effect of its own fire, and to minimize the damage done by that of the enemy. Within effective ranges everything must give way to these two considerations.

3. For the front or "firing line" the only formation, both in attack and defense, which meets these requirements, is a line of small sections extended in single rank (which are called a line of skirmishers), which from being at first very open becomes more and more dense as the antagonists come to close quarters, attaining at last almost the consistency of a line in close order.

4. This "firing line" has a very different mission to that of the old "line of skirmishers." The latter had only to prepare the way for the columns or lines and to supplement their efforts; the former, on the contrary, has to fight the battle out through all its stages to the very conclusion, being supported in doing so by the troops in close order.

7. A tactical body once thrown into a firing line on the offensive cannot be relieved; its remnants, great or small, will remain in the firing line to the end of the action.

8. The comparatively loose formations necessary in the present day render supervision and control on the part of superiors more difficult. Tactical dispositions will again do something to remedy this evil, but *thorough discipline and training will do more*, contributing, as they will, to the complete maintenance of the chain of responsibility, from the Commander-in-chief right down to the leader of the smallest squad in the fighting line.

9. The importance of the company as a battle unit is much increased, and *pari passu* the importance of the Captain as a commander.

13. The tactical desiderata for an ideal defensive position are: First and foremost, a clear field for fire, both to the front and flanks, for some three thousand yards; secondly, ground sloping gently downwards towards the

enemy; thirdly, well-secured flanks, and no prominent salient angles; fourthly, good cover for supports and reserves at a convenient distance from the fighting line; fifthly, good sheltered communications from the rear and along the position; sixthly, good positions for batteries in rear and on higher ground than infantry.

15. Good infantry need not fear the attack of cavalry, even if in extended order. As a general rule they should be able to maintain the formation in which they happen to be when threatened. To do otherwise will be only to play the enemy's game.

19. A mere passive defense will produce no great result. A commander when on the defensive must always be prepared to make a counter-attack at the right moment."

These selections teach us to undo much we have been taught to do. They bring to our notice that the ideas we still hold to in instruction are of but little use in action, and that the company commander now is the one on whom much of the onus of the fight will fall. The responsibility does not now rest with one or two men, but with all, from the Commander-in-chief to the private, and the responsibility being so much more divided, the instruction must be so much more extended and perfected.

The tactical desiderata give us the ideas we want; continual practice must be had to enable one to take advantage of the ideas taught. The styles of firing have changed so much now that the instruction must be changed and the soldier or sailor made almost an expert with the rifle, and especially with the repeating rifle. The instructions given must be with a view to a careful nursing of supply until the critical moment, the efficiency of group firing and the supreme importance of entire attention to orders given by the company officers.

The last but by no means the least important article (19) shows how very important it is for the Commander-in-chief of the force to be one capable of seizing upon any and every opportunity that chance or bad management on the opposing side may offer to him by which some advantage may be gained. It shows that a careful selection should be made in giving command of an expedition, not giving it to rank, but to the one known to be the best military commander.

From page 5 to 8 the details of infantry fighting are dwelt upon, considering the distribution of a battalion acting by itself on the offensive. In these pages the divisions of the company are given (each nation having a paragraph to itself), and its actions as the "advanced company in the first stage of the fight." Also "the rest of the battalion during the first stage." Page 8 commences the second stage of the fight, which supposes the attacking force to be about 500 yards from the enemy's position. "Put off the moment of opening fire as long as you can, and get as near the enemy's position as possible before doing so," is the German idea. The French say at 650 yards fire should be opened along the whole line, while Austria leans more to the German idea and only admits of general firing at 300 paces. The kind of fire employed by Germany is either volleys (those of the line or groups), individual (or skirmishing) fire, and rapid independent fire, but it is insisted that from the moment fire is opened it should become general, because the object of the assailant is to subdue the defender's fire so as to facilitate his own advance. France only allows rapid independent fire with the 200-metre sight. Austria, while recognizing only one sort of fire when in extended order, that of individual firing, yet, in the case of men in close order, admits of volleys and of independent firing. Pages 11 and 12 are devoted to gaining ground under fire; page 13 to supports and reserves under fire, and to the assault. The storming distance as considered by Germany is not less than 200 yards on open ground, and we would quote these words: "The maximum distance to be traversed in the final charge must depend upon the physical powers of the assailants, as there must be no check. This rush must be in one inning. The maximum distance must therefore greatly depend upon whether the ground is flat or whether there is a steep gradient, again,

whether the soil be at the time light or heavy." The French say the assault should commence at the point beyond which the assailant can make no further progress by the effect of his firearms alone. Austria considers 80 to 100 paces as the maximum distance to be traversed when storming. "By whom will the order for the charge be given?" Germany gives it to the leaders of the foremost bodies. France gives it to no specified person, but seemingly to the battalion commander. Austria allows it to the leaders of the fighting line. The execution of the assault and after the assault are referred to on pages 14 and 15, and this rule is held to by all: "Infantry not to pursue the retreating enemy, but only to fire after them. If woods or villages are carried, their further borders should be occupied at once. The interior should be well searched by a portion of the reserve, which should at once rush up to the position, the remainder joining in the fire on the retreating enemy."

Pages 16 to 21 are given to the "single battalion on the defensive," and on page 17 we find these words: "A commanding officer has thus to provide a sufficiently strong fighting line; next, to feed and reinforce it at need; thirdly, to keep in hand a general reserve; fourthly, to set apart a special body to execute the counter-attack when the proper time comes; and, lastly, to make his tactical dispositions in such a manner as to prevent as far as possible, or, at any rate, to delay to the utmost any intermixture of units." "A defensive action resolves itself into two stages: 1. that of distant fire; 2. that of near fire. The boundary between the two being the moment when the fighting line of the assailants is brought to a standstill and begins to reply effectively to the fire of the defenders." Page 17 also considers the "first stage of the defense." "The object of the defender is to delay the assailant and to make his approach to storming distance as difficult as possible. This must be the work of the rifle, and the question is how best to use it." The Germans tend to volley firing at this stage, first, against deep columns exposing themselves, then, against company columns and lines, lastly, against skirmishers. The French fire, part against skirmishers and the remainder at the supports and reserves. Pages 18 and 19 dwell upon the second stage of the defense, "which reaches its climax when the assailant is preparing to storm. At that moment the defender must bring every disposable rifle into action, except the reserve kept in hand for a counter-attack. Troops brought up at this moment should be in close order; they risk little, for the enemy will be stopping his fire to make his assault, and they will be more under control. This is specially the moment, and one of the few moments, when rapid independent fire is advisable." Page 19 also refers to the counter-attack and further measures. "The necessity of combining the offensive with the defensive, and of not trusting to a mere passive defense, is universally admitted. The question is, When and how is the defender to take the offensive?" Page 20 gives the ideas of the three nations upon this part of the action if the defense is a successful one, or, if unsuccessful, sets forth the different modes of withdrawal. Page 21 sums up a defensive action as follows:

"1. Reconnaissance of the position. Construction of defensive works. Patrols sent out for security.

2. Occupation of the position. As a rule, two companies side by side, each divided into fire-line and supports. The other companies in reserve on one or both flanks.

3. Commence firing volleys at long ranges on marks easily hit. If good opportunities offer, the supports are moved up into the fire-line for short periods.

4. At short ranges independent fire is used. Supports reinforce the firing-line, coming up as a rule by groups.

5. The enemy makes his assault. The defender's reserves move up into line and fire volleys. If possible, a counter-attack upon the flank of the enemy.

6. The defenders pour a heavy fire upon the retiring enemy, or themselves retreat by successive echelons."

This finishes the consideration of the single battalion. A short space is given

to "Infantry against Cavalry," in which all agree that "if attacked by cavalry, infantry should allow itself to be as little disturbed as possible from the formation in which it happens to be. Skirmishers may even receive cavalry without closing if the ground be at all favorable to them. A body of troops in close order had best receive cavalry in line if already deployed or if it have time to do so." Germany has three forms of squares for this defense—battalion, company, and group or rallying squares. France uses company squares, but neither of the others. A battalion in open column forms company-columns and echelons them, or forms line. A battalion in line of company-columns, echelons the companies so that they may support one another. Austria uses rallying squares for skirmishers and company squares for supports, but a battalion attacked by cavalry forms the same as the French. From page 22 to page 28 a battalion forming part of a larger body is considered; on the offensive, (1) battalions in rear line; (2) extent of line; (3) the assault; on the defensive, battalions in rear line. From page 28 to page 37 the question of infantry battle tactics in Russia is considered, and on page 37 is given a comparison between the French and German infantry tactics of the present day, written by an experienced French officer, and which will give to any one interested in tactics for the foot soldier many excellent points. The pamphlet, taken as a whole, is one that should be carefully studied, and it should be in the possession of every one whose duty it may be to have charge of a landing force in either this or any other country. Naval officers can study it to great advantage, for the time is near when we must change our present system to one comprising as principles many of the points laid down in this work.

COMBUSTIBLE FOSSILS, REFRACTORY MATERIALS, AND THE IRON INDUSTRY AT THE NATIONAL EXPOSITION OF TURIN IN 1884.

By L. Adami, Colonel of Artillery.

(Supplement to the *Rivista d' Artiglieria e Genio.* Translated by W. F. Worthington, P. A. Engineer, U. S. N.)

Bituminous coal is not found in Italy; the only combustible fossils are anthracite coal and lignite. There are about fifteen localities in Italy where anthracite has been found, but none of them of much commercial importance, as the anthracite is generally of indifferent quality, containing much earthy matter, is in small and distorted veins, and difficult to excavate.

Lignite, on the other hand, is found in abundance and in many localities, and being in some cases of excellent quality, gives rise to an industry of considerable importance. There is one mine, only slightly explored as yet, which contains lignite of such good quality that many scientists consider it bituminous coal. With regard to calorific values, three units of the best lignite are equal to two of ordinary bituminous coal, and of the inferior lignite two units are equal to one of bituminous coal. Besides inferiority in calorific value, some of the lignites have other qualities, such as giving off great volumes of smoke, unpleasant odor, sulphur sufficient to damage fire boxes, also taking fire spontaneously, crumbling and falling through the grate. Many of them produce much clinker which sticks to the grate. The best kinds of lignite are adapted for use in steam boilers for stationary engines, metallurgical, glass, terra-cotta, cement and other furnaces. Other kinds are even better for the same purposes after having been previously artificially dried. The worst kind may be used for the same purposes, but when used to convert pig iron into wrought iron or steel must be burned in a Siemens regenerator or other such furnace. They are not adapted for use in cupolas.

CONGLOMERATES.—The name conglomerate (agglomerato) is given to bricks composed of coal dust mixed with tar (catrame) and subjected to pressure. The bricks are adapted for use in stationary and locomotive boilers and in other industries. Their principal advantages are the small losses which occur in transport, the convenience of handling, and the small space occupied. Their calorific value can never exceed that of the best bituminous coal, and they are necessarily more costly. In Italy this manufacture is very limited, and only introduced to utilize the small quantity of dust from imported coal. The bricks are composed of coal dust and tar (brai-grasso), or of olive seeds (sanze), tar (brai), petroleum residue, schist (scisto), benzine, residual paraffine, stearine and other oleaginous materials. The latter composition, called the Rubino combustible, of which the principal ingredient (80 per cent to 90 per cent) consists of olive seeds, deserves special notice. There are about 500,000 tons of "sanze" produced annually, and the patentee claims that this would furnish enough of his fuel to supply all the requirements of the country both on land and sea. It is to be noted, however, in this connection that the annual importation of bituminous coal is 2,000,000 tons. He claims for the fuel the calorific value of 6800 calories (bituminous coal about 7000—W. F. W.), that it is free from dust, saves the grates, furnaces and boilers, produces no clinker and contains no sulphur, and is 30 per cent to 50 per cent cheaper than other fuels, according to the locality. It should be remembered that much of the "sanze" is now used for fuel in the neighborhood of the oil factories, and if it was all bought up for the manufacture of bricks the price of the latter would rise considerably. Nine varieties of the fuel are produced, each adapted to a special purpose. Experiments made with the fuel in the furnace of a steam-boiler showed 8 kilos of steam at five atmospheres pressure, evaporated per kilo of the fuel, the cost of which latter was about one-half the cost of Cardiff coal. There was no trouble in managing the fire, the fuel did not adhere to the bars or form clinkers, burnt with a beautiful flame and little smoke, was readily lighted, and the bricks burnt regularly and uniformly. The ash was small in quantity, perfectly white, and easily disposed of.

COKE.—As there is no bituminous coal in Italy, the only coke produced is that left from the manufacture of illuminating gas, and is not useful for metallurgical purposes.

TURF.—The scarcity of combustible fossils and the increasing destruction of the forests render even the deposits of turf valuable. The use of this material only dates back about 25 years, but is now quite extensive, even being used in the Siemens regenerative furnace and steam boilers on land and on the lakes. Its calorific value is about the same as that of good lignite, *i. e.* about one-half that of bituminous coal. It occurs almost exclusively in the valley of the Po.

Conclusion.—In the arsenals the native fuels, with the exception perhaps of the Rubino combustible, are not fit to be used in the reverberatory furnaces (forni a riverbero) or in the muffles (forni a manica), but may be used for any other purposes.

REFRACTORY MATERIALS.—Graphite is found in some parts of Italy well adapted for making refractory crucibles, for use as a lubricant for machinery, and mixed with oil forms a varnish for iron. It is used principally, however, for the manufacture of pencils, and is also exported.

FIRE CLAY, FIRE BRICKS, AND CLAY CRUCIBLES.—There is a serious deficiency in good fire clay. Most of the native clays soften at the highest temperature of the iron furnace, and are therefore not well adapted for making fire bricks.

THE IRON INDUSTRY.—Italy is relatively rich in iron ores. Scarcely one-quarter of this is smelted in the country; the remaining three-fourths are exported. The reason for this is the small supply of good native coal and wood charcoal. The native cast iron, however, is of the best quality, and for the manufacture of cast iron guns, that from Lombardy is equal to the best Swedish pig.

[The paper concludes with a short account of the facilities for the manufacture of gun steel and projectiles at the time of the Exposition. Besides the few facts selected for this notice, the paper has full tables of the quantities and qualities of the various materials and the localities in which they are found, and altogether is well worth careful study by both friends and enemies of Italy, the capacity for manufacturing guns and machinery being at the base of a country's military strength.—W. F. W.]

AMERICAN STEEL FOR THE NEW CRUISERS.

COMMANDER ROBLEY D. EVANS, U. S. N., Chief Inspector of material for the new cruisers, in conversation with a Washington newspaper correspondent, has made some interesting statements in regard to the quality of steel now being produced by our American manufacturers. As the subject is one of interest to the members of the Institute, we give in full his statements as printed in *The Iron Age* of June 16.

"I think the manufacturers of steel to supply the demands of the Government contracts will agree with me that the system of inspection and the high requirements of the physical properties of the material have done much to promote a higher standard of production than has ever been achieved in the United States. At first the manufacturers looked upon the inspections as unnecessarily severe, but since they have been gathering important lessons by experience they have commenced to realize that it has been to their advantage.

"Let us take the ship plates manufactured by the Park establishment, of Pittsburgh, for the Cramps, of Philadelphia. At first they had great trouble. After weeks of testing and intelligent manipulation the standard was reached, and they are now delivering plates of a better standard than any manufactured abroad. They are up to the best French, and better than the English plates.

"Now let us look at Carnegie, Phipps & Co. They at first experienced the greatest difficulty in the production of ship and boiler material. Now they are delivering the very first quality. I remember the first shoe plate for the cruiser Baltimore. It was 1¼ inches thick and considered an impossibility. After repeated experiments and personal attention I had the pleasure of congratulating the makers not only upon the successful rolling of the plate, but upon the highest and most satisfactory tests. They can now roll any number required without the slightest trouble.

"Now take rivets. The requirements in the specifications were so exacting that several firms declined the contracts. Oliver Brothers & Phillips, who make steel by the Clapp-Griffiths process, finally accepted. At first they met with doubtful success, but after a few weeks' drilling under the eyes of the inspectors they came up to all the requirements. They are now making the rivets right along up to standard. They admit that the Government inspection has not only been an advantage as bringing the steel up to a high standard, but that it has been of advantage to the workmen by teaching them to be careful."

"How about castings?"

"I was about to say that steel castings made under Government contracts surpass everything anticipated. Indeed, so marked has been the success in that direction that Mr. Cramp proposes to use steel castings in parts of ships where it was never used before. The castings for the stern-post and rudder-train and other parts of these vessels have been successfully made by the Standard Steel Casting Company, of Thurlow, and the Midvale Steel Works, of Nicetown, Pa. In fact, results have been achieved far beyond the claims of the most sanguine believers in steel castings.

"This is among the Eastern manufacturers. Now let us turn to the West. It is somewhat remarkable that the Pacific Rolling Mills, of San Francisco, considering the short time they have been in operation, are turning out steel for the California ship which in regularity of physical properties surpasses anything made by Eastern firms. The reports we have of 20 heats, averaging 20 tons to the heat, fall between 60,000 and 62,000 pounds ultimate strength, with an elongation of 28 per cent, 25 per cent being the maximum requirement.

"The steel for the frames and shapes made by the Pennsylvania Steel Company, at Steelton, and rolled by the Phœnix Iron Company, are also beyond what was looked for so soon after the Government work was undertaken.

"With all these practical results it can be said that the Government has done much for metallurgical production in the United States. Better material is being put into the new vessels for the Navy than has ever been put in any ship in the United States, and, as far as the records in our possession show, better than has been put in ships abroad. I think Mr. Cramp and Chief Engineer Melville will agree with me in this."

A record of the results of these inspections is being kept by Lieutenant F. J. Milligan, U. S. N. It will undoubtedly be of great value not only in giving a history of the material used in each ship, but from a scientific point of view.

C. R. M.

SYSTEM FOR SIGNALING TO AN APPROACHING VESSEL THE POSITION OF THE HELM.

This system, invented by Captain Staves, and for which he has received a medal at the Liverpool Exposition, and also the thanks of Lloyd and the Board of Trade, consists of two standards placed one on each bow and at such a height as to be clear of the sails. Each standard has at its top a light of the same color as the side light; *i. e.* green to starboard and red to port, as also a semaphore arm of the same color. The normal condition of these is, lights masked and arms down. If the helm is put to either side, on seeing a vessel approaching, the officer of the deck by working a lever either unmasks the corresponding light or raises the corresponding arm.

D. H. M.

BOOK NOTICE.

AZIMUTH: A TREATISE ON THIS SUBJECT. By Lieutenant-Commander Joseph Edgar Craig, U. S. Navy. New York: John Wiley & Sons.

We are pleased to acknowledge the receipt of "Azimuth: A Treatise on this Subject," by Lieutenant-Commander J. E. Craig. The masterly manner in which the subject is treated shows that the author has given the subject many hours of careful and faithful study, and the results arrived at show that the old time and generally accepted theories, as to the best positions of heavenly bodies for azimuth observations, have been derived more from snap judgments than from penetrating mathematical deductions. As the author remarks, ordinary observations at sea do not exact the best conditions of observation, but there are doubtless many cases in which too much labor cannot be given to obtain the best results, and the author has pointed out the way in which this accuracy may be reached.

The treatment of the various loci discussed and drawn shows a deep and thorough knowledge of the subjects involved, and commends itself to the mathematical mind as a lucid and graphic illustration of how such a subject as this may be opened to the observer who will devote a few hours to perusal and study.

We congratulate the author sincerely, not only on the subject-matter of his work, but on the attractive form in which he has presented it to the public.

BIBLIOGRAPHIC NOTES.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

15TH ANNUAL SERIES, 1887, No. 3. Studies of the ice in the harbor of Kiel. Hydrographic notes on voyage between Koepang, Island of Timor, to Cooktown. The Island Ascension. Notes on Benguela, Santa Maria Bay, and Mossamedes, on the west coast of Africa. The Island of Mackau, Corean Archipelago. Notes from the voyages of several German merchant captains. Report on the harbor of Zebu, Philippine Islands. Pauta Delgada, Island of St. Michael, Azores. Instruments for measuring currents, and current measurement in the Bosphorus. Deep-sea sounding in the North Atlantic. Current observations, temperature observations, North Atlantic. Tracks of typhoons around Japan, and hints for avoiding them. Rains in the Indian Ocean. Short notices. Tables of average temperature, meteorological and magnetic observations.

E. H. C. L.

SERIES 1887, No. 4. Observations on the Earth's Magnetism by the Polar Expedition, 1882–3. The Malimba and Blundo Rivers, south coast of Africa. Expedition of the Fylla to Baffins Bay in 1886. Meteorological and Hydrographic Notes: Part V. Samana Bay, San Domingo, West Indies. Nimrod Sound, China. Geographical, Meteorological, and Hydrographic Notes. J. T. S.

BULLETIN OF THE AMERICAN IRON AND STEEL ASSOCIATION (quoting from the *Iron Trade Review*).

The use of petroleum as fuel.

This fuel is used successfully in the Bay State Steel Works, South Boston, Mass., but has been abandoned on the steamers of the Union Pacific Railroad. Dr. Kauffmann reports to the Russian Government that petroleum can be solidified into bricks and still retain its calorific properties. He says: "Petroleum, which is a hydrocarbon of the methane group, may be saponified just like the oils, fats, fatty acids, and wax, thus oxidizing the oil and combining it with soda or potassa salts. For this purpose the oil is heated and from one to three per cent of common soap is added, with which it is boiled for half an hour. The soap dissolves and the fluid turns suddenly to a hard, putty-like substance. It lights with difficulty, burns slowly without smoke, producing great heat, and leaving about two per cent of odorless, black, hard residuum."

W. F. W.

BULLETIN OF THE AMERICAN GEOGRAPHICAL SOCIETY.

No. 3, 1886. Florida and the West Indies. Over the Mexican plateau in a diligence. Geographical Notes.

No. 4, 1886. Some of the geographical features of South-eastern Alaska. The origin of the name America. On the extermination of the great Northern sea-cow (*Rytina*). Ancient habitations of the Southwest. Geographical Notes.

No. 5, 1886. Table of contents, etc., for Vol. XVIII. Transactions of the Society for the year 1886.

No. 1, 1887. Oceanic Islands: their physical and biological relations. New Mexico: its geography, scenes, and peoples. Stone-Pasha's work in geography. Geographical Notes.

No. 2, 1887. The great walled river. Recent explorations in Egypt. Colonel Chaillé-Long on the Juba. Geographical Notes. Obituary: Vice-President Roswell S. Hitchcock, D. D.

J. H. G.

ENGINEER.

APRIL 15, 1887. Compound versus triple expansion marine engines.

The same engine was worked alternately as compound and triple expansion, and the conclusion deduced that more I. H. P. per pound of coal was obtained in the latter case, but more knots per ton of coal in the former.

The Italian ship Dogali had her official trial trip, and is the fastest cruiser afloat. The mean speed over the measured mile was 19.66 knots; I. H. P. 7600; revolutions, 154. W. F. W.

ENGINEERING.

FEBRUARY 25, 1887. Torpedoes and war ships.

APRIL 1. Torpedo boat trials (from Proceedings of Institute of Naval Architects).

Results of trials to determine the value of m in the formula $v = m\sqrt[3]{\frac{\text{I. H. P.}}{B^2}}$ (the usual formula employed in France). B = area of midship section and m a coefficient of efficiency. The value of m was found to increase up to 11 knots, attain a minimum at 17 knots, and to increase slightly at higher speeds.

Paper on the twin-screw torpedo boats Wiborg and El Destruidor (from Proceedings of Institute of Naval Architects).

Valuable paper on scientific iron founding, with special reference to mechanical character and chemical composition.

APRIL 8. On the corrosion of iron and steel ships.

With the aid of a galvanometer it was found that rust is quite as capable of setting up galvanic action as the magnetic oxide, even if the action be less intense.

Liquid fuel experiments.

A trial of a new furnace invented by Lieutenant Pashinin and used on a river steamer in Russia, showed that 1 pound of petroleum refuse evaporated 15.6 pounds of water, or 2¼ times as much as 1 pound of coal.

Paper on fuel supply in ships of war.

APRIL 15. Comparative effects of belted and internal protection upon other elements of design of a cruiser (from Proceedings of Institute of Naval Architects).

Last week the trials of H. M. S. Anson were made with 94 pounds of steam and 97 revolutions; the I. H. P. was 8320 and speed 16½ knots; consumption of coal 2.3 pounds per I. H. P. With both screws working ahead the port half circle was turned in 2 minutes 28 seconds; the complete circle, 640 yards diameter, was turned in 5 minutes 15 seconds. The starboard half circle was turned in 2 minutes 46 seconds, and the complete circle, 650 yards diameter, in 5 minutes 47 seconds. On the forced draught trials the steam pressure was 101 pounds; revolutions 108.6 port, 108.9 starboard; I. H. P., 12,568; consumption of coal 2.2 pounds per I. H. P.; speed, 17.4 knots..

On high-speed twin screws (from Proceedings of Institute of Naval Architects), with following table:

Particulars of Some Recent High-Speed Twin Screws.

SHIP.	A.	B.	C.	D.	E.
Length in feet	325	315	300	220	250
Breadth	68	61	46	34	32½
Draught on trial { Forward	26′ 2″	24′ 6″	15′ 6″	12′ 10″	13′ 1″
Draught on trial { Aft	27′ 3″	25′ 6″	19′ 9″	15′ 2″	14′ 7″
Displacement in tons	9690	7645	3584	1560	1544
I. M. S., square feet	1560	1287	744	438	392
Speed of ship, knots	16.92	17.21	18.18	16.91	17
I. H. P.	11,610	10,180	6160	3115	3045
Revolutions per minute	107.2	88	122.6	150.4	132.1
Pitch of screw	19′ 5″	22′	17′ 6″	12′ 7½″	14′ 9″
Slip, per cent	17.6	10	14.2	9.7	11′ 4″
Diameter of screw	15′ 6″	18′	13′	10′ 6″	11′
Diameter of boss	4′ 4″	4′ 11″	3′ 5″	2′ 9″	2′ 10″
Number of blades	4	4	3	3	3
Blade area of one screw	72	87	47	24	24
Pitch / Diameter	1.25	1.22	1.34	1.2	1.34
Disc / Blade area	2.62	2.92	2.82	3.6	3.96
Immersion of screw	9′	5′ 3″	4′ 4″	2′ 9″	1′ 10″

APRIL 29. Twin-screw torpedo boat (illustrated).

This boat is one of two built for the Italian Government by Yarrow & Co. Its length is 140 feet; beam, 14 feet; displacement, 100 tons; mean of six runs on measured mile in rough weather, 25.1 knots; revolutions, 274½; steam, 130.

The belted cruiser Orlando.

Her length is 300 feet; beam, 56; displacement, 5000 tons; draught forward, 20 feet, aft, 22 feet. The trial was for four hours with forced draught of 1¼ inches and the vessel loaded down to water line. Steam pressure, 129 pounds. Total I. H. P. 8622. The helm was put hard over (70°) in thirty seconds, and the circle, 480 yards, was made in three minutes, the shortest time in which it has ever been done by a vessel of her length. On the measured mile a mean speed of over 19¼ knots was attained, the highest ever attained by a British armed vessel.

A fast torpedo boat.

This boat, built by Thorneycroft & Co. for the Spanish Navy, attained a mean speed of 26.1 knots on a recent trial. Her length is 147 feet 6 inches; beam, 14 feet 6 inches; draught, 4 feet 9 inches.

Triple-expansion engines.

A comparison of the results of the working of eleven compound and nine triple-expansion engines showed a gain in economy of about 25 per cent in favor of the latter. W. F. W.

JOURNAL DU MATELOT.

APRIL 24. Interesting account of the use of oil in a violent storm, by the steamer Dragut.

MAY 29. Means for preventing collisions, a system of sound signals, by Captain Frémont, of Havre, France. D. H. M.

MECHANICAL ENGINEER.

FEBRUARY 26. Account of the testing and breaking of one of the steel shafts made for the U. S. S. Boston.

MARCH 26. Article on modern high-speed marine engines, giving a number of details.

MAY 7. Cost of electric lighting of vessels (from report of P.-A. Engr. G. W. Baird, U. S. N.).

The expenditures for one year were as follows:

14¾ tons of coal, at $5.17 per ton	$76 25
43½ gallons of oil, at 55 cents per gallon	23 92
149 lamps, at 35 cents	126 25
34 3-light safety plugs, 18 of 6 lights, 1 of 30 lights	4 24
2 key sockets, 4 plain sockets	3 80
3 wire shade holders, at 30 cents	90
3 pounds copper wire, at 40 cents	1 20
2 pounds insulation tape, at 50 cents	1 00
1½ gross assorted screws, at $1.25	1 87
46 feet flexible cord, at 15 cents	6 90
4 attachment plugs, at 40 cents	1 60
3 dynamo brushes, at 60 cents	1 80
1 standard, at 44 cents	44
Total	$249 98

The dynamo was in operation 1574 hours 26 minutes, and during that time a mean of 47 lamps were in circuit. The cost of the light was .042 cent per candle power per hour. The mean life of a lamp in the engine room was 932 hours 54 minutes. These lamps were in circuit all the time, and were lighted and extinguished by the starting and stopping of the dynamo.

The forced draught system on the U. S. S. Alliance.

The system was devised by the Bureau of Steam Engineering, and by it the I. H. P. per square foot of grate was increased from 4.02 to 12.38. The ash pan doors are closed instead of the stoke hole.

Test of steel screw blades for the U. S. naval cruisers (made by P.-A. Engr. C. R. Roelker, U. S. N.).

The strain put upon the blades was in each case 2.3 times the maximum which would occur with the blade in use. The deflection was remarkably uniform, and increased gradually from root to tip. W. F. W.

RAILROAD AND ENGINEERING JOURNAL.

MAY. Ribbed boiler tubes.

These tubes have longitudinal internal ribs, invented by M. Chomienne, and are manufactured in France by "La Societé Industrielle et Commerciale des Métaux." It is said they can be made almost as cheaply as smooth tubes, and are just as easy to sweep with the tube brush. Comparative trials of smooth tubes and ribbed ones in the boilers of a steamer on the Rhone, showed in one case a saving of 35 per cent, and in another case a saving of 24 per cent by the use of the latter tubes. By changing from smooth to ribbed tubes in one case, the heating surface was doubled and the calorimeter reduced only one-fifteenth.

JUNE. Large steel castings.

The Standard Steel Casting Co., of Thurlow, Pa., recently turned out and shipped to Philadelphia, a steel stem casting weighing 15,000 pounds for a gunboat building by Cramp & Sons, and a stern casting weighing 13,000 pounds, the first of cast steel ever made in the United States. Also sixteen cast-steel propeller blades for the Chicago, Boston, and Atlanta. The weight of each blade for the former ship was 2410 pounds, and for the two latter ships 3750 pounds. W. F. W.

REPORT ON EXPERIMENTAL FIRING AT THE CAST STEEL FOUNDRY OF FRIEDRICH KRUPP, AT THE PROVING GROUNDS AT ESSEN AND MEPPEN.

No. 67, 1887. Tests of experimental firing with 8.4-cm. rapid-firing ship's guns L/27.

The gun itself remains as previously described, excepting a change in the chamber to suit the new combined cartridge and shot. The carriage has been considerably modified, the lower pyramidal carriage resting on balls, on which it trains. The recoil of the upper carriage is taken up by hydraulic cylinders. The gun is elevated by an endless screw working into a toothed arc. The training is effected by a similar arrangement. Weight of projectile 7 kg.; charge, 1.6 to 1.7 kg.; cubical powder (?) of 10 mm.; initial velocity, 470–480 m. With a trial powder the initial velocity vas increased to 506 m. It takes three men to work the gun; one man sits on the seat and sights the gun. He has the firing string attached to a belt around his body. He fires by throwing his body

back. Rapidity of fire, 10 shots in 34 seconds, or at the rate of 18 shots a minute. They were fired at the bow of a torpedo boat, distant 400 metres. The middle fore and aft line of the bow was in the line of fire, and the bow plates stood at 15° to each other and perpendicular on the ground. The steel plates had strength of 5 m. All the shot hit, as will be seen on diagram. Later 7 shots were fired in 19 seconds, or at the rate of 22 per minute. Therefore, in one minute $7 \times 22 = 154$ kg. weight of shot can be fired with $80{,}000 \times 22 = 1{,}760{,}000$ m. kg., *vis-viva*. This is the best result yet obtained by rapid-firing guns. E. H. C. L.

REVUE DU CERCLE MILITAIRE.

No. 12, MARCH 20, 1887. Military forces of Canada.

No. 13, MARCH 27. Torpedoes and torpedo boats. The French fleet, January 1, 1887. New infantry equipment in Germany.

No. 16, April 17. New equipment for French infantry.

No. 17, April 24. Trials with the Maxim revolving guns. Experiments with new repeating rifle at Vienna, Austria.

No. 19, MAY 8. Launch of Austrian turret vessel, Princess Stefanie, at Trieste, giving general description, armament, lighting, and machinery.

No. 23, JUNE 3. New equipments for German infantry, giving several different views. D. H. M.

REVUE MARITIME ET COLONIALE.

MAY. Instrument for self-registering the rolling of a ship. The Legion of Honor (continued). Study on the combined operations of fleets and armies, commencement of Volume V., Volumes I., II., III. and IV. having been published in 1882–'83. Austrian expedition to the Island Jan-Mayen (continued). Observations made at New Foundland on board the frigate La Clorinde during the cruise of 1886.

JUNE. Continuation of the combined operations by sea and land. Under the head of "Chronique," or selections from other papers, is an article from the Marine Engineers, describing an apparatus intended to signal the position of the helm to an approaching vessel. This position can be shown either at day or at night. (See Professional Notes, present number.) D. H. M.

RIVISTA MARITTIMA.

FEBRUARY.

The French Minister of Marine has issued a circular, from which the following is extracted with regard to the care of the boilers of torpedo boats. Upon lighting fires the blowers are not to be used, but natural draught is to be depended upon. The fires are not to be urged, but to be regulated in such manner that a steam pressure will begin to show after one and three-quarter

hours. Allowing ten or fifteen minutes for the pressure to rise to five or six kilos, it will be two hours from the time of lighting fires before the torpedo boat is ready to move. The blowers will not be started until the torpedo boat is in motion, and then only gradually. When the torpedo boat is in motion, except in case of absolute necessity, of which the commanding officer is to be the sole judge, all sudden changes of speed are to be avoided, and especially all sudden stops when the engine is working full power. Changes of speed both of the engine and of the blowers should be made gradually and progressively. The doors of the boiler compartments should never be entirely opened or shut at once, but gradually. When the fires are to be hauled, the steam pressure should be allowed to fall some time before the engine is stopped, and at the same time slow down the blowers gradually, aiming to stop them just as the engine stops. The steam pressure may be relieved either through the safety valves or the bleeding valve to the condenser. If, when the engine is stopped, the fires are heavy, they may be partly hauled by taking out a few of the grate bars. If, on the other hand, they are not too heavy, they may be left as they are. The furnace and ash-pit are then to be shut air-tight, the cover put on the smoke-pipe and on the air-pipe from the blowers, and then, or at least on the following day, the boiler compartment is to be shut and left to cool down gradually.

The Minister of Marine has proposed a reorganization of the corps of the Navy, the most important change being in the Engineer Corps (Ufficiali Meccanici), who were to be completely assimilated (in rank—W. F. W.) to the line officers, the highest to have the rank of fleet captain (Capitano di Vascello). The parliamentary committee, to whom the proposed law was referred, did not favor the changes, and especially that relating to the status of the engineers. W. F. W.

TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Vol. VIII. The new calorimeter.

Paper giving tabulated results of boiler tests made with a new calorimeter. This instrument works on an entirely different plan from any other. The principle of operation is to evaporate the moisture held by the steam, and measure its quantity by determining the amount of heat required for this purpose. The instrument is described at length in Vol. VII., p. 178, of the Transactions.

Capital's need for high-priced labor.

The paper and following discussion treat of the wage question at length and in detail. The conclusion is reached that, "as a general rule, large wages return many times as much value to the shops as low wages." Also it is better to pay each laborer in proportion to what he does than to pay the same wages to all engaged in the same class of work. W. F. W.

UNITED SERVICE GAZETTE.

March 26. Convoys; are they any longer possible?—discussion on.

April 2. Belligerent rights; and what is lawful in war time—discussion on. A new gun for the Royal Navy, Armstrong, is a 30-pounder, weight with carriage 92 cwt.—intended for repelling torpedo attacks. Carriage fitted with Vavasseur's patent automatic machinery. Muzzle velocity 1900 feet.

APRIL 16. Improvements in camp kitchens, field cooking, camp equipage, and military transport. Trial of a new plate made by Cammell & Co.; no shells penetrating, the steel shells being completely broken up.

MAY 14. Launch of the Sans Pareil at Blackwall.

Dimensions: Length, 340 feet; breadth, 70 feet; depth, 37 feet 6 inches; displacement, 10,470 tons; engines, 7500 to 12,000 H. P. Armament, two 16-inch 111-ton guns, twelve 6-inch 5-tons, nine 3-pounder quick-fire, one 10-inch 29-ton gun, twelve 6-pounder quick-fire, two 1-inch Nordenfeldt, eight 14-inch Whitehead torpedo tubes, and four 0.45-inch Nordenfeldt. The Sans Pareil has eighteen inches steel-faced armor.

Launch of the new composite sloop Buzzard.

Length, 195 feet; breadth, 30 feet; draught, 12 feet 2 inches; displacement, 1075 tons; 2000 H. P. Armament, eight 5-inch B. L. guns. Unarmored, but vital parts are protected by a steel deck running the whole length of ship.

MAY 21. An article on torpedo boats.

JUNE 11. Launch of the Immortalité at Chatham.

A twin-screw belted cruiser 300 feet long, 56 feet wide; draught forward, 19 feet 6 inches; aft, 22 feet 6 inches; displacement, 5000 tons; I. H. P., 8500; speed, 18 knots. Principal battery, two 9.2-inch B. L. and ten 6-inch B. L. Steel-faced belt ten inches thick, and iron plating at end of belting sixteen inches thick.

JUNE 18. Blockades under existing conditions of warfare. The second torpedo attack upon the Resistance. D. H. M.

LE YACHT.

MARCH 12. P. 84: Submarine boats. P. 90: Turnabouts, description and plans of these little vessels, French and English. P. 91: The new cruisers building in France.

MARCH 19. P. 95: The French manœuvres of 1887; a criticism on the orders given for the contests between the fleets and torpedo boats. P. 98: Hill and Clark's boat detaching apparatus, drawings and description. P. 101: El Destructor, giving dimensions, etc.; also, some of the chief faults in her construction.

APRIL 2. P. 115: The Nice, French cruiser for cadets. P. 116: Trial of the Camperdown's engines. View and description of the rudder of the Spanish torpedo boat (cruiser) El Destructor.

APRIL 9. P. 119: Torpedo boats and Mère Gigogne.

The Mère Gigogne is thus described: She will be designed to carry six torpedo boats; will be an armored vessel, with 35-cm. plates, armed with two 34-cm. guns; also, repeating cannon and rapid fire guns. She must have great speed. Plans for such a vessel have been advertised for, and she will probably cost over twelve million francs.

P. 122: English sea-going torpedo boats.

This article mentions the Rattlesnake, Grasshopper, Spider, and Sandfly, giving dimensions, armament, and trials of speed of Rattlesnake.

APRIL 16. P. 131: Description of Mr. Trouve's electric engines for small boats, showing plans of battery; arrangement for electric ventilator and fog horn and electric boat lights.

APRIL 30. P. 145: Plan and description of apparatus for pouring oil on the sea from ships. P. 147: Manœuvres of torpedo boats in Mediterranean. System of protection against torpedo boats.

MAY 7. P. 155: Description and view of torpedo boat Ouragan. P. 156: Manœuvres of torpedo boats. Launch and description of the Neptune. Trial of cruising battery Sfax at Brest.

MAY 14. Before the manœuvres; referring to the operations about to be carried on by the French between a fleet of ironclads and a fleet of torpedo boats. P. 163: Trials of a new style of gunboat.

MAY 21. P. 171: Protection of fighting ships and Melinite projectiles. P. 173: Accidents at sea, and means for preventing them.

MAY 28. P. 181: Fog signals. P. 185: Launch and description of French iron-clad Marceau. The iron-clad barbette vessels of the English Navy. P. 186: The English torpedo flotilla.

JUNE 4. P. 199: Recent auto-mobile torpedoes.

JUNE 11. P. 211: Description and chart of the canal from the North Sea to the Baltic.

This canal was inaugurated June 3, 1887, by the Emperor of Germany.

End of article on recent auto-mobile torpedoes. D. H. M.

REVIEWERS AND TRANSLATORS:

Lieut. E. H. C. LEUTZE, U. S. N., Lieut. D. H. MAHAN, U. S. N.,
Lieut. J. T. Smith, U. S. N., P.-A. Eng. W. F. WORTHINGTON, U. S. N.,
Ensign JOHN H. GIBBONS, U. S. N.